STB-HA-365
Revision: Basic

Hazard Analysis for Pneumatic Flipper Suitport/Z-1 Manned Evaluation, Chamber B, Building 32

Crew and Thermal Systems Division
Systems Test Branch

September 14, 2012
Revision: Basic

Verify this is the correct version before use.

Crew and Thermal Systems Division
Engineering Directorate
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Houston, Texas

Hazard Analysis for Pneumatic Flipper Suitport/Z-1 Manned Evaluation, Chamber B, Building 32

September 14, 2012

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Change Record

Revision	Date	Originator	Description
Basic	September 14, 2012	Robert Seiwell	Initial release.

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Tables and Figures

1.0 Introduction/Purpose

One of the characteristics of an effective safety program is the recognition and control of hazards before mishaps or failures occur. Conducting potentially hazardous tests necessitates a thorough hazard analysis in order to protect our personnel from injury and our equipment from damage.

The purpose of this hazard analysis is to define and address the potential hazards and controls associated with the Z1 Suit Port Test in Chamber B located in building 32, and to provide the applicable team of personnel with the documented results. It is imperative that each member of the team be familiar with the hazards and controls associated with his/her particular tasks, assignments, and activities while interfacing with facility test systems, equipment, and hardware.

The goal of this hazard analysis is to identify all hazards that have the potential to harm personnel and/or damage facility equipment, flight hardware, property, or harm the environment. This analysis may also assess the significance and risk, when applicable, of lost test objectives when substantial monetary value is involved. The hazards, causes, controls, verifications, and risk assessment codes have been documented on the hazard analysis work sheets in appendix A of this document.

The preparation and development of this report is in accordance with JPR 1700.1, JSC Safety and Health Handbook.

2.0 Scope

This Hazard Analysis covers only those activities associated with the functional test for Chamber B in Building 32 and specifically those activities associated with the Z1 Suit Port Testing preparation for the test. It is also meant to cover the manned testing of the Z1 suit in Chamber B.

As applicable, the safety assessment considers/reviews the following elements of the test, hardware, or facility system.

A) Test System/Facility Hardware – Structural, Mechanical, Electrical, Chemical, Test Environment, Static/Dynamic Energies, Materials

B) Test personnel training and interaction with hardware, facility and/or test system

C) Test Procedures, Equipment Operating/Task Instructions, Check Lists, Equipment/Component Configurations, Drawings and Schematics, and Preventative Maintenance.

3.0 References

Note: All references must be reviewed prior to use to verify/confirm that the document is the latest revision.

3.1 Documents

Document Number	Revision	Document Title
		ASME Boiler and Pressure Vessel Code, Section VIII, Division 1
		Z-1 Rear Entry Closure and SPIP Finite Element Analysis, Dated October 2011
29 CFR 1910		OSHA Safety Standards for General Industry
29 CFR 1926		OSHA Safety Standards for the Construction Industry
ASME B31.1	A	Power Piping
ASME B31.3		Process Piping
ASME B31.5		Refrigeration Piping and Heat Transfer Components
ASME HSP		High Pressure Systems
ASME PVHO-1		Pressure Vessel Code for Human Occupancy
BBMU-1006	E	Chamber B Inspection and Seal Pretest Checklist
BBMU-1007	K	Chamber B Facility Instrumentation and Power Pretest Checklist
BBMU-1008	H	Chamber B Facility Instrumentation and Power Post Test Checklist
BBMU-1009	H	Chamber B Manlock Pretest Checklist

Document Number	Revision	Document Title
BBMU-1010	D	Chamber B Manlock Post Test Checklist
BBMU-1024	B	Chamber B Remote Door Pretest Checklist
BBMU-1025	C	Chamber B Remote Door Posttest Checklist
BBMU-1038		Chamber B In-Chamber Can GN2 Purge Pretest Checklist (Includes Mass Spec Preparation)
BBMU-1039		Chamber B In-Chamber Can GN2 Purge Post Test Checklist (Includes Mass Spec Shutdown)
CTSD-ADV-536		AEVA Communications System Hazard Analysis Report
CTSD-ADV-819	A	Hazard Analysis for Spacesuit Audio Communication Interface System I & II (SPACIS I & II)
CTSD-ADV-908	A	Operating Procedures for the Low Pressure Outlet 6 K-Bottle Manifold
CTSD-ADV-947	A	Checkout and Standard Use Procedures for the Z – 1 Space Suit Assembly (SSA)
CTSD-ADV-949	A	Hazard Analysis for the Z-1 Space Suit Assembly (SSA) Used in One-g Operations
CTSD-ADV-0958		Chamber B Suitport Blanking Plate Delta-Pressure Evaluation Detailed Test Procedure
CTSD-ADV-1002		Chamber B Pneumatic Flipper Suitport Unmanned Evaluation Detailed Test Procedure
CTSD-ADV-1003		Pneumatic Flipper Suitport/Z- Manned Evaluation, Chamber B, Building 32
CTSD-SH-1447	A	CTSD Control of Hazardous Energy Lockout – Tagout Process
CTSD-SH-1448		CTSD Energy Source Isolation (ESI) Procedure
EA-WI-024		General Operating Procedures Manual for EA Testing Facilities
ES4-12-084		Operation and Configuration Control Plan (OCCP) for Safe Ground Pressurization of Pneumatic Flipper Suitport (PFS) and Blanking Plate at Johnson Space Center (JSC)
ESCG-4450-05-STAN-DOC-0115		Stress Analysis for the Chamber B Manlock B1 Floor Modification.
ESCG-4450-12-STAN_DOC-0056		Stress Analysis for the Pneumatic Flipper System
FFM-1003		Chamber B Oxygen Supply Cart Bottle Changeout Checklist
FFMU-1001	D	Chamber B SCU Oxygen Supply Cart #2 Pretest Checklist
FFMU-1002	C	Chamber B SCU Oxygen Supply Cart #2 Post Test Checklist
JJMU-1001	G	Chamber “B” Fire Suppression System Arming Checklist
JJMU-1003	G	Chamber “B” Fire Suppression System Pretest Checklist
JJMU-1005	D	Chamber B Fire Detection and Suppression System Pretest Checklist – Fire Technician
JPG 5322.1	G	Contamination Control Program Requirements Manual
JPR 1700.1	J, with Change 3	JSC Safety and Health Handbook
JPR 1710.13	F	Design, Inspection, and Certification of Ground-Based Pressure Vessels and Pressurized Systems
JPR 8080.5		JSC Design and Procedural Standards Manual
JSC 09604		Materials Selection List for Space Hardware Systems
JSC 17773	D	Preparing Hazard Analysis for JSC Ground Operations
NASA/SP-2010-3407		Human Integration Design Handbook (HIDH)
NASA-STD-8719.9	w/ change 1	NASA Standard for Lifting Devices and Equipment
NFPA 70		National Electrical Code (NEC)
NFPA 72	2007	National Fire Alarm Code

Document Number	Revision	Document Title
NHB 8060.1	B	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion
NPR 8000.4	Change 1	Risk Management Procedural Requirement
NPR 8715.3	C	NASA General Safety Program Requirements
NPR 8719.11	A	Safety Standard For Fire Protection
OOMU-1001	A	Chamber B Facility cooling Water Pretest Checklist
STB-063		Chamber B Entry Procedure
STB-1039	K	Chamber B Toshiba Process Control System Startup Procedure
STB-1106	H	Chamber B Fire Suppression Functional Checkout
STB-E-083	A	CTSD Materials Control Procedure and Materials Selection Criteria
STB-E-367	C	Hazard Analysis Preparation Procedure
STB-E-554	D	STB Test Operations Guideline
STB-E-557	C	STB Facility and Major Test Buildup Procedure
STB-E-557	C	STB Facility and Major Test Buildup Procedure
STB-E-574		Systems Test Branch Facility Maintenance Procedure
STB-F-001	N	Crew and Thermal Systems Division (CTSD) Systems Test Branch General Operating Procedures Manual (GOPM)
STB-F-1017	A	Cleaning Procedure for chamber A & B Interiors & Manlock
STB-F-1040	J	Chamber B Toshiba Process Control System Shutdown Procedure
STB-F-1042	M	Chamber B Static Checkout of Emergency Repress System Auto Mode (Computer Control)
STB-F-1042	M	Chamber B Static Checkout of Emergency Repress System Auto Mode (Computer Control)
STB-F-1044	D	Chamber B Emergency Repress Arming Procedure Manuel Mode
STB-F-1045	G	Chamber B Emergency Repress Arming Procedure Auto Mode (Computer Control)
STB-F-1046	G	Chamber B Emergency Repress Charging Procedure
STB-F-1048	B	Chamber Repress and Ventilation Pretest Procedure Manual Mode
STB-F-1049	C	Chamber B Repress and Ventilation Pretest Procedure Auto Mode (Computer Control)
STB-F-1076	B	Chamber B Vacuum Rough Pumping System Procedure Manual Mode
STB-F-1083	G	Chamber B Electrical Procedure Head Removal and Replacement
STB-F-1084	D	Chamber B Mechanical Procedure Head Removal and Replacement
STB-F-1085	A	Chamber B Angle Valve Cycling Procedure
STB-F-1086	D	Chamber B Repress and Ventilation Operating Procedure Manual Mode
STB-F-1087	E	Chamber B Repress and Ventilation Operating Procedure Auto Mode (Computer Control)
STB-F-1088	C	Chamber B Vacuum Rough Pumping System Procedure Auto Mode
STB-F-1100		Chamber B Decay Rate Test For Emergency Repressurization Instrument Air System
STB-F-1102		Chamber B Pre & Post Test Solar Utilities Operating Procedure
STB-F-1103		Chambers A & B Leak detection Procedure
STB-F-1108	B	Chamber B Operation of Manlock B-1 Remote Operated Door
STB-F-1133	D	Chamber B, Manlocks B1 & B2, UV Detector System Checkout Procedure
STB-F-1134	E	Chamber B Manlocks B1 & B2 Power Interrupt Circuit Checkout Procedure
STB-F-1138	C	Chamber B Cryogenics Operation Procedure for CRYO-3 Operator
STB-F-1147		Permit-Required Confined Space Procedure (PRCS) For Working Inside Chamber “B”, Building 32
STB-F-1156		Emergency Repress and Circulation Duct Purge Procedure for Chamber “B”
STB-F-1183		Chamber B Liquid Nitrogen for Linde Helium Refrigerator cryo-1 Operation Procedure

Document Number	Revision	Document Title
STB-F-1192		Calibration Procedure for Analyzer in B32
STB-F-1196		Chamber B Manlock PLC Software Verification Procedure
STB-F-1197		Chamber B Manlocks PLC Operating Procedure
STB-F-1217		Users Manual
STB-F-1218		Operation and Maintenance Manual
STB-F-361	K	Electrical Guidelines for Facility Modifications and Test Build-Ups
STB-F-366	H	Mechanical Guidelines for Test Facilities and Buildups
STB-F-452	B	Instrumentation Engineer’s Guidelines
STB-F-544	B	Control of Hazardous Energy Lockout/Tagout Procedures
STB-F-621		Electrical Safety – Related Work Practices
STB-F-627	A	Controlled Hazard System Procedure
STB-HA-033	B	Hazard Analysis for the CTSD Thermal Vacuum Test Complex, Buildings 32, 32Q
STB-HA-328		Hazard Analysis for Cooling Tower Chemical Automation Upgrade, Building 32
STB-HA-336		Hazard Analysis for Unmanned Functional Test, Chamber B, Building 32
STB-HA-343		Hazard Analysis for the Liquid Nitrogen System (LN_2) for Chamber B, Building 32
TTMU-1001	F	Chamber “B” Emergency Repressurization Pretest Checklist
WWMU-1001	J	Chamber B Communications System Pretest Checklist
WWMU-1002	D	Chamber B Communications System Posttest Checklist

3.2 Drawings/Schematics

Drawing Number	Sheet	Revision	Title
BB02-E20000	1	D	Ch B Manlock Valves PLC Controls Power Distribution
BB02-E20010	1	B	Ch B Manlock Valve Automation MLB1 Operator Panel
BB02-E20010	2	C	Ch B Manlock Valve Automation MLB1 Operator Panel
BB02-E20020	1	B	Ch B Manlock Valve Automation MLB2 Operator Panel
BB02-E20020	2	C	Ch B Manlock Valve Automation MLB2 Operator Panel
BB02-E20030	1	C	Ch B Manlock Valve Automation PLC Bypass Relays
BB02-E20040	1	A	Ch B Manlock Valve Automation Operator Panel Calibration Pigtail
BB02-E20060	1	F	Ch B Manlock Valve Automation PLC Wiring
BB02-E20060	2	F	Ch B Manlock Valve Automation PLC Wiring
BB02-E20060	3	D	Ch B Manlock Valve Automation PLC Wiring
BB02-E20721	1	C	Schematic Diagram Manlock Facility Status Display, Bay 2 Chamber “B” Test Directors Console
BB02-E20725	1	D	Schematic Diagram Chamber “B” Manlock Door Position Signal To T/D Console
BB02-M01000	1	D	Vacuum System Chamber “B” Manlock Vacuum Control System Building 32 Mechanical
BB02-M01000	2	E	Vacuum System Chamber “B” Manlock Vacuum Control System Building 32 Mechanical
BB02-M01000	3	C	Vacuum System Chamber “B” Manlock Vacuum Control System Building 32 Mechanical
BB02-M01000	4	F	Vacuum System Chamber “B” Manlock Vacuum Control System Building 32 Mechanical
BB03-M01000	1	C	P and ID Vacuum Diffusion Pumps Chamber “B” Building 32
BB03-M01000	2	B	P and ID Vacuum Diffusion Pumps Chamber “B” Building 32
BB03-M02000	1	E	P&ID Vacuum Backing System Chamber “B”

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BB03-M02000	2	F	P&ID Vacuum Backing System Chamber “B”
BB09-E20000	1	E	Monorail Controls Control Panel Layout Building 32, Chamber B
BB09-E20000	2	I	Monorail Controls Control Panel Layout Building 32, Chamber B
BB09-E20000	3	G	Monorail Controls Control Panel Layout Building 32, Chamber B
BB09-E20000	4	DNE	Monorail Controls Control Panel Layout Building 32, Chamber B
BB09-M20800	1	F	GN2 Supply for Ingress/Egress Motor, Bldg 32 Chamber B
BB25-E05500	1	A	Building 32 Chamber B Suit Port AB PLC Control Panel Layout
BB25-E05500	2	A	Building 32 Chamber B Suit Port AB PLC Relay Outputs Wiring
BB25-E05500	3	A	Building 32 Chamber B Suit Port Bulkhead #1
BB25-E05500	3	A	Building 32 Chamber B Suit Port AB PLC Analog Inputs Wiring
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BB25-E05500	6	A	Building 32 Chamber B Suit Port AB PLC SSI Encoders Wiring
BB25-M55000	1	A	Chamber B Suit Port Installation
BB25-M55000	1	A	Breathing Air for Suit Port – Chamber B
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BB25-M55001	1	A	Breathing Air For Suit Port – Chamber B
BB25-M55002	1	A	Chamber B Suit-Port Vestibule Repress/Depress
BB25-M55004	1	A	Chamber B Suit Port Inflatable Seal
BB25-M55005	1	A	Pneumatic Flipper Air For PFS Suitport Chamber B
GG01-E20597	1	I	Top Drawing, Test Power Control System
GG07-E20516	1	N	Schematic Control Diagram LN2 & He Systems
GG07-E20516	2		Schematic Control Diagram LN2 & He Systems
GG07-E20516	3	G	Schematic Control Diagram LN2 & He Systems
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GG07-E20537	1	O	Schematic Instrumentation Diagram Diffusion Pump System, Ch B
GG07-E20537	2	H	Schematic Instrumentation Diagram Diffusion Pump System, Ch B
GG07-E20537	3	D	Schematic Instrumentation Diagram Diffusion Pump System, Ch B
GG07-E20537	4	B	Schematic Instrumentation Diagram Diffusion Pump System, Ch B
GG07-E20537	5	B	Schematic Instrumentation Diagram Diffusion Pump System, Ch B
GG08-E01000	1	O	Test Directors Control Panel
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GG08-E01000	3	G	Test Directors Control Panel
GG08-E01000	4	D	Test Directors Control Panel
GG08-E01501	1	D	Chamber Select Chassis – Electrical Schematic, Building 32
GG08-E01501	2	B	Chamber Select Chassis – Electrical Schematic, Building 32
GG08-E01501	3	E	Chamber Select – Electrical Schematic, Building 32
JJ01-E00100	1	J	Schematic Diagram Chamber B Fire Detection & Suppression Panels FS1 & FS2
JJ01-E00100	2	G	Chamber B Fire Detection and Suppression Panels FS1 & FS2
JJ01-E00100	3	A	Chamber B Fire Detection and Suppression Panels FS1 & FS2
JJ01-E00100	4	D	Fire Suppression & Detection System Chamber Wiring Connections for Alarm Functions at Pane FS1
JJ01-E00100	5	C	Chamber B Fire Detection and Suppression Panel FS1 Layout Door Front View

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JJ01-E00100	6	A	Chamber B Fire Detection and Suppression Panel FS1 Layout Door Rear View
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JJ01-E00100	8	A	Chamber B Fire Detection and Suppression Panel FS1 Layout Inner Panel View
JJ01-E00101	1	E	Chamber B Manlock Power Interrupt Cabinet RB3
JJ01-E00101	2	H	Chamber B Manlock Power Interrupt Cabinet RB3
JJ01-E00101	3	E	Chamber B Manlock Power Interrupt Cabinet RB3
JJ01-E00102	1	H	Chamber B Ultra Violet Detection System
JJ01-E00200	1	A	Building 32 Overall Location Plan General Conduit Routing Plan
JJ01-E00202	1	A	Fire Suppression and Detection System – Chamber A & B
KK02-M20450	1	B	Chamber “A” and “B” Deionized Water System Instrumentation
KK02-M20460	1	A	C Water System Instrumentation
OO01-E00000	1	B	Building 32 Cooling Tower Shed Electrical Schematic
OO01-E00000	2	A	Building 32 Cooling Tower Shed Electrical Schematic
OO01-M00002	1	A	P&ID Cooling Water – Chamber “B” Area Mechanical
OO01-M00002	2	A	P&ID Cooling Water – Chamber “B” Area Mechanical
OO02-M01000	1	G	Compressed Air System Building 32
OO02-M01000	2	H	Compressed Air System Building 32
OO02-M01000	3	B	Compressed Air System Pump Room Building 32
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OO02-M01000	5	D	Compressed Air System Tank Farm Building 32
OO02-M01000	6	E	Compressed Air System Cryo Room Building 32
OO02-M01000	7	B	Compressed Air System Miscellaneous Components Building 32
OO02-M04000	1	D	Compressed Air System Building 32 Chamber B
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OO02-M04000	3	B	Compressed Air System Building 32 Chamber B
OO02-M04000	4	A	Compressed Air System Building 32 Chamber B
OO02-M04000	5	B	Compressed Air System Building 32 Chamber B
OO02-M04000	6	B	Compressed Air System Building 32 Chamber B
OO02-M04000	7	D	Compressed Air System Building 32 Chamber B
OO05-M00000	1	B	Cooling Water System Cooling Tower & Supply
OO05-M00000	2	D	Cooling Water System Cooling Water Closed Loop
OO05-M00100	1	B	Cooling Water System Roughing Pumps Supply & Ret.
OO12-E00001	1	A	PLN21A Motor Starter Circuit (B32 LN2 Loading Pump)
TT02-E20600	1	C	ER System Purifier and Compressor Controls Building 32
TT03-M01000	1	EE	Emergency Repressurization System Chamber “B” Mechanical – P & ID
TT03-M02000	1	F	Normal Repressurization Heating & Ventilating System Chamber “B”
TT03-M03000	1	M	ER Compressor System Chambers A & B Building 32
VV01-M00100	1	D	Vacuum System Rough Pumping System Building 32 Chambers A & B Training Schematic
VV01-M00100	1	D	Vacuum System Rough Pumping System Building 32 Chambers A & B Training Schematic
VV01-M01000	1	H	Vacuum System Vacuum Rough Pumping System
VV01-M01000	1	H	Vacuum System Vacuum Rough Pumping System Building 32 Mechanical
VV01-M01000	2	D	Vacuum System Vacuum Rough Pumping System Building 32 Mechanical

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VV01-M01000	2	O	Vacuum System Vacuum Rough Pumping System
VV01-M01000	3	A	Vacuum System Vacuum Rough Pumping System
VV01-M01000	3	A	Vacuum System Vacuum Rough Pumping System Building 32 Mechanical

4.0 Symbols and Abbreviations

Symbols & Abbreviations	Explanation
AR	Air Release Valve
ASME	American Society of Mechanical Engineers
ATD	Assistant Test Director
BTU	British Thermal Unit
BTU/hr	BTU/hour
C or ^{o}C	Degrees Celsius
CDR	Critical Design Review
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CIL	Critical Items List
CK	Check Valve
COTS	Commercial Off the Shelf
COV	Cylinder Operated Valve
CTSD	Crew and Thermal Systems Division
CV	Diaphragm Operated Butterfly Valve
DARAC	Data Acquisition Recording and Control
DR	Discrepancy Report
DTP	Detailed Test Procedure
DV	Designated Verifier
ER	Emergency Repress
ESCG	Engineering and Science Contract Group
E-STOP	Emergency Stop
F or ^{o}F	Degrees Fahrenheit
FEE	Facility Engineer, Electrical
FEM	Facility Engineer, Mechanical
FM	Failure Mode
FMEA	Failure Mode and Effects
FOD	Foreign Object Debris
ft	Feet
ft^2 or sq. ft.	Square Feet
ft^3 or cu. ft.	Cubic Feet
GFCI	Ground Fault Circuit Interrupt
GFE	Government Furnished Equipment
GHe or He	Gaseous Helium
GN_2 or GN2	Gaseous Nitrogen
GSE	Ground Support Equipment
HA	Hazard Analysis
HA	Hazard Analysis
HAWS	Hazard Analysis Work Sheet
hp	Horsepower
HST	Hoist

Symbols & Abbreviations	Explanation
HV	Hand Valve
HX	Heat Exchanger
IE	Instrumentation Engineer
JHA	Job Hazard Analysis
JPD	JSC Policy Directive
JPR	JSC Procedural Requirement
JSC	Johnson Space Center
JSC	Johnson Space Center
K or ^{o}K	Degrees Kelvin
L	Light
L or l	liter
lbs or lb_f	Pounds force.
LN_2 or LN2	Liquid Nitrogen
LPF	Lunar Plane Floor
m	Meter
MOV	Motor Controlled Valve
MCC	Motor Control Center
MSC	Manned Space Center
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Agency
NE	Northeast
NEC	National Electric Code
NFPA	National Fire Protection Association
NPR	NASA Procedural Requirement
NW	Northwest
P	Pump
PDR	Preliminary Design Review
PFS	Pneumatic Flipper System
PM	Preventative Maintenance
POC	Position Operating Controller
PPE	Personal Protective Equipment
PRV	Pressure Relief Valve
RAC	Risk Assessment Code
RCA	Radio Corporation of America
RUD	Rupture Disc
RV	Relief Valve
S/C	Space Craft
SE	Southeast
SESL	Space Environment Simulation Laboratory
SHT	Sheet
SOV	Solenoid Operated Valve
STB	Systems Test Branch
SW	Southwest
TD	Test Director
TK	Tank
TPS	Task Performance Sheet
UIC	Programmable Controllers
URR	Use Readiness Review
VAC	Vacuum
VR	Vacuum Relief Valve

Symbols & Abbreviations	Explanation
W	Watts
W/ft^2	Watts per square foot
W/m^2	Watts per square meter

5.0 Definitions

The following definitions are vital to an understanding of the requirements contained in this document:

a. Hazard — An unsafe or unhealthful condition that could lead to a mishap if it is not corrected.

b. Consequence — The subjective estimate of worst credible outcome in terms of potential personnel injury, equipment/facility damage, and monetary losses. Consequence severity classes are defined as follows.

Class I – Catastrophic.
A condition that may cause death or permanently disabling injury, facility destruction on the ground, or loss of crew, major systems, or vehicle during the mission; schedule slippage causing launch window to be missed; cost overrun greater than 50% of planned cost.

Class II – Critical.
A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, equipment, or flight hardware; schedule slippage causing launch date to be missed; cost overrun between 15% and not exceeding 50% of planned cost.

Class III – Moderate.
A condition that may cause minor injury or occupational illness, or minor property damage to facilities, systems, equipment, or flight hardware; internal schedule slip that does not impact launch date; cost overrun between 2% and not exceeding 15% of planned cost.

Class IV – Negligible.
A condition that could cause the need for minor first-aid treatment but would not adversely affect personal safety or health; damage to facilities, equipment, or flight hardware more than normal wear and tear level; internal schedule slip that does not impact internal development milestones; cost overrun less than 2% of planned cost.

c. Likelihood — The relative likelihood a hazard may occur. The complete likelihood range is separated into intervals for additional classification. It is important to note that even though quantitative probability intervals are listed in this document they are only for numeric comparison and that the actual probability or likelihood is derived by subjective estimations of a qualitative nature. The hazard likelihood categories are defined as follows.

Likelihood A – Likely to occur
Likelihood B – Probably will occur
Likelihood C – May occur
Likelihood D – Unlikely to occur
Likelihood E – Improbable

d. Risk Assessment Code (RAC) — The risk assessment code is the numerical value that represents the hazard risk associated with a given task, project, test, or equipment and is the point of intersection of the consequence severity estimate and the likelihood estimate on the RAC matrix.

e. Risk Assessment Code (RAC) Matrix — A matrix made up of likelihood estimates, consequence severity estimates, and risk assessment codes. The matrix is used to derive the risk assessment code once the consequence and likelihood have been determined.

f. Hazard Disposition — The status of a hazard after controls are in place. Hazard Dispositions are utilized in this analysis, documented at the bottom of each hazard analysis worksheet, to supplement the risk

assessment codes and to further describe the control or status of the hazard. The disposition criteria are defined as follows:

Open/no action — A hazard exists in the system, and no controlling equipment or procedures have been implemented to minimize the hazard.

Closed/controlled — A hazard exists in the system, and appropriate mechanical/electrical/procedural actions have been taken to reduce the hazard to a minimal level.

Closed/eliminated — A hazard that is no longer in the system because it has been eliminated.

Closed/accepted — A hazard of RAC 2 or 3 after controls whose risk has been accepted by NASA management.

g. Hazard Summary — A list of the hazard categories/titles with before and after control RAC's.

h. Verification — The validation method or process that confirms the hazard control. Verifications of the hazard controls are identified via review of test procedures, equipment operating instructions and checklists, test system drawings and schematics, personnel training records, applicable JSC, EA, Division, and Branch work instructions and operating procedures, inspection of test equipment/area and interviews with facility engineers, technicians, test directors, and management.

i. Hazard Analysis Worksheet (HAW) — Tables in the hazard analysis used to document specific information regarding each hazard or hazard category, such as hazard title/description/consequence, system, sub-system, RAC, hazard causes, controls, verifications, remarks, and hazard disposition. There is only one hazard category/title per HAW.

j. The RAC matrix is defined as follows:

Table 1 – Risk Assessment Code Matrix

CONSEQUENCE CLASS	LIKELIHOOD ESTIMATE				
	A	B	C	D	E
I	1	1	2	3	4
II	1	2	3	4	5
III	2	3	4	5	6
IV	3	4	5	6	7

k. The table below specifies the required action(s) for each RAC.

Table 2 – RAC Action Table

RAC	Action
1	Unacceptable – All operations must cease immediately until the hazard is corrected or until temporary controls are in place and permanent controls are in work. A safety or health professional must stay at the scene at least until temporary controls are in place. RAC 1 hazards have the highest priority for hazard controls.
2	Undesirable – All operations must cease immediately until the hazard is corrected or until temporary controls are in place and permanent controls are in work. RAC 2 hazards are next in priority after RAC 1 hazards for control. Program Manager (Directorate level), Organizational Director, or equivalent management is authorized to accept the risk with adequate justification
3	Acceptable with controls – Division Chief or equivalent management is authorized to accept the risk with adequate justification
4-7	Acceptable with controls – Branch Chief or equivalent management is authorized to accept the risk with adequate justification

6.0 Hazard Identification Criteria

As applicable, the following sources were utilized in developing the potential hazards, cause, controls, and verifications in this Hazard Analysis:

- System design drawings, schematics, and Configuration Change Orders
- Failure Modes & Effects Analysis
- Detailed Test Procedures, Task Performance Sheets, Checklists, Preventative Maintenance Instruction
- Test system, equipment/hardware, and facility visual inspections
- Review of lessons learned and accident/mishap/injury reports
- Discussion with the test team, design engineers, test article experts, and management
- Materials review for toxicity, contamination, and compatibility/reactivity with system or test environment

6.1 Design Order of Precedence Mitigation of Identified Hazards

- **Eliminate hazards through design selection.** If unable to eliminate an identified hazard, reduce the associated mishap risk to an acceptable level through design selection.
- **Incorporate safety devices.** If unable to eliminate the hazard through design selection, reduce the mishap risk to an acceptable level using protective safety features or devices.
- **Provide warning devices.** If safety devices do not adequately lower the mishap risk of the hazard, include a detection and warning system to alert personnel to the particular hazard.
- **Develop procedures and training.** Where it is impractical to eliminate hazards through design selection or to reduce the associated risk to an acceptable level with safety and warning devices, incorporate special procedures and training. Procedures may include the use of personal protective equipment. For hazards assigned Catastrophic or Critical mishap severity categories, avoid using warning, caution, or other written advisory as the only risk reduction method.

6.2 Risk Reduction Protocol

Hazards are control through the following protocol:

1. Eliminate the mishap scenario. Eliminate the hazard or initiating event by design.
2. Reduce the likelihood of mishap scenarios through design and operational changes (Hazard Controls.)
3. Reduce the severity of the mishap consequences (Hazard Mitigation).

4. Improve the state-of-knowledge regarding key uncertainties that drive the risk associated with a hazard

7.0 Discussion/Description of Chamber B, the Z-1 Suit, and the Suit Port.

7.1 Chamber B Physical Description

Chamber B, with roughly one tenth of the internal volume of Chamber A, can handle a variety of smaller scale tests more economically and with faster response. Chamber B is a human-rated chamber. It is equipped with a traversing monorail that provides weight relief to one suited crewmember at a time. The traversing monorail allows two degrees of freedom inside the chamber and 18.6 square meters (200 square feet) of working space.

Major structural elements of the chamber are the removable top head, the fixed chamber floor, dual crewlocks at the floor level, and a load bearing floor area of 6.1 meters (20 ft) in diameter that will support a concentric load of 34,000 kg (75,000 lb).

The dual crewlocks provide easy access to the test articles as well as a means of transporting test crewmembers to the test environment and back during tests. The crewlocks are also be used as an altitude chamber for independent tests. One crewlock is equipped with a water deluge system and other features that permit its use for crew operations with oxygen-rich residual atmospheres.

Additional test support equipment includes an internal jib crane, mass spectrometers, infrared cameras, use of television cameras, and two rolling bridge cranes with a capacity of 45,000 kg (100,000 lb), which are used to remove the chamber top and insert large test articles.

A solar simulation array, mounted on the top head, is modular in design to facilitate changes in location and beam size accommodating a wide range of test requirements. The solar simulation modules are on axis with xenon lamp sources. The source and collection optics are located outside the chamber, with collimating optics inside the chamber. Solar incident angles other than vertical can be achieved by installing mirrors in the chamber to redirect the solar beam.

7.1.1 General Characteristics

The chamber has outside dimensions of 10.7 m (35 ft) diameter x 13.1 m (43 ft) high. This provides working dimensions of 7.6 m (25 ft) diameter x 7.9 m (26 ft) high. The maximum test article weight is 34,000 kg (75,000 lbs) concentric load. It has real-time data acquisition and remote control.

Access to the chamber is via a 10.7 m (35 ft) diameter removable top head or dual crewlocks at floor level.

The vacuum system uses staged roughing pumps, valved and trapped oil diffusion pumps, and 20 K (-424 ^{o}F) cryopumps. The pump down time is approximately 5 hours to test conditions. The pumping capacity is 1 x 10^{7} liters/sec condensables and 2 x 10^{5} liters/sec noncondensables at 1 x 10^{-6} Torr pressure. (Note: Usual chamber leakage is less than 3 x 10^{5} liters/sec of air at 1 x 10^{-6} Torr pressure.) Repressurization is controllable from 90 sec minimum; chamber dryout using dry gas purge and heated shroud and floor at vacuum.

The heat sink and special thermal simulators for the full chamber shroud are subcooled 90 K (-298 ^{o}F) LN_2 shroud 130,000 W total heat absorption capacity, 1615 W/m^2 (150 W/ft^2) maximum heat flux. The wall emissivity is 0.95. The special simulators are Solar, Aledo, and planetary radiation. The solar simulation is achieved by a top sun using 1 to 37 xenon modules producing a 6.1 m (20 ft) diameter beam maximum; modules can be located anywhere within a 6.1 m (20 ft) diameter circle. The decollimation angle is 90-minutes half angle with an intensity of 622 to 1353 W/m^2 (58 to 126 W/ft^2) controllable and a uniformity of +/-5 percent measured with 930 cm^2 sensor. The measurement of this is accomplished with a Real-time traversing radiometer system. Solar incident angles other than horizontal can be achieved by installing mirrors to redirect the solar beam.

7.1.2 Vacuum System Description

The vacuum systems uses staged roughing pumps, ten (10) valved and trapped oil diffusion pumps, and two (2) 20 K (-424 F) cryopumps. The vacuum system schematics are shown below. The pump down time is approximately 5 hours to test conditions. The pumping capacity is 1 x 10^{7} liters/sec condensables and 2 x 10^{5}

liters/sec noncondensables at 1 x 10^{-6} torr pressure. (Note: Usual chamber leakage is less than 3 x 10_{-5} liters/sec of air at 1 x 10^{-6} torr pressure.) The system is comprised of four (4) pumps and four (4) blowers. An emergency repressurization system is available. This repressurization is controllable from 90 sec minimum; chamber dryout using dry gas purge and heated shroud and floor at vacuum.

The vacuum pumping equipment associated with Chamber B is similar to the equipment used on Chamber A. The roughing system is common to both chambers, although the chambers cannot be evacuated simultaneously.

The four-stage rough pumping train is located in Building 32, room 1903. The third and fourth stages consist of identical parallel trains which are both required during normal operation. Each third stage has two pumps, one of 730 cfm and the other of 310 cfm capacity. Intercoolers are provided between stages. The first stage is bypassed until its inlet pressure reaches 10 torr. The first and second stage intercoolers are bypassed below 0.1 torr to improve system conductance. The system will evacuate Chamber B to a pressure of 8.5 x 10^{-3} torr with a total gas load of 33.9 torr-liters per second.

Figure 1 – Chamber B

There are ten (10) diffusion-pumping stations for Chamber B, each consist of a 48-inch diameter elbow with an integral right angle admission valve, a 48 – 36 inch transition piece, and a 36-inch diffusion pump using DC-705 pump fluid. Each station has a pumping speed of approximately 50,000 liters per second at $1x10^{-4}$ torr. To reduce back streaming, the elbow and transition piece for the diffusion pumps are cooled with 40 ^{o}F water. The transition piece is equipped with a water cooler plate baffle for optical density. The admission valve is equipped with a hydraulic operator, which permits throttling during the first six inches of travel, and closure from the full open position with 30 seconds in the event of an emergency repressurization. All valves

on the chamber can be controlled simultaneously from the central control room. The diffusion pumping system will evacuate Chamber B to 1.4 x 10^{-4} torr. Chamber B can reach 1.1 x 10^{-4} torr with the gas load cited above.

In addition to the ten (10) diffusion pumps, Chamber B has two (2) PHPK TM1200 cryopumps. These cryopumps are located in pump stations 10 & 12. The admission valve for these two (2) pumps is a 48 in normally closed gate valve. These two pumps will allow the chamber to be pumped down even farther (1 x 10^{-5} torr).

Chamber B has a diffusion pump backing system consisting of two parallel two-stage pump trains. The first stage blower does not start until the vacuum reaches 0.3 torr in the foreline. During initial pump down, both trains are operated, but during normal operation, one train can maintain the diffusion pump discharge pressure at less than 250 microns. By closing the train inlet vale, the other train to be placed in an on-line standby status.

In addition to the main vacuum trains, Chamber B has two parallel three-stage manlock pumping trains. The second-stage units consist of two mechanical pumps, one (1) with 730 cfm capacity, and one (1) with 140 cfm capacity. The first stage blower starts at 10 torr and is equipped with a bypass that closes below 0.8 cfm. There are intercoolers after the first and second stages. The first stage intercooler bypass opens at 0.1 torr to improve conductance at lower pressures. One train can evacuate a manlock to 5 x 10^{-3} torr in less than 18 minutes.

All vacuum pumping systems are equipped with gaseous nitrogen systems for purging and mechanical pump ballasting. Most of these systems respond automatically, although a few purge connections are manually controlled due to operational requirements. Each manlock has an altitude control system that gives automatic control of manlock pressure at any level from atmospheric down to 15 torr. Below 15 torr, the altitude control system is isolated and does not govern manlock pressure. The system is comprised of an inbleed system coupled to the evacuation system described above. Automatic controls limit the rate of pressure change to less than 100 torr per minute and will hold the pressure at a preset set point. A secondary control loop acts to minimize the load on the pumping train by simultaneously throttling the inbleed and evacuation system. An additional controller starts and holds the manlock at preset pressure following an emergency repressurization.

7.1.3 Chamber B Manlocks B1 and B2

Chamber B manlock pressure control is performed by the Programmable Logic Controller (PLC). The main power distribution is configured to the uninterruptible power supply (UPS). Each manlock is provided with a dedicated control panel located in front of each manlock exterior. The control panel provides auto depress/repress and emergency repress modes.

For the Pneumatic Flipper Suit Port Unmanned Evaluation, Manlock B1 will be used as part of the chamber. This will give increased volume and pumping train. This will give increased volume and pumping train. Manlock B1 will be depressurized to as low as 2.2 psia. Manlock B2 will be used as a staging area for the test and will remain at sea level pressure throughout the evaluation. A two-piece bulkhead, installed between the main chamber and Manlock B2, accommodates Suitport testing and acts as a pressure seal. The bulkhead has the interface for mounting the Suitport and various feed-throughs used for data collection instrumentation and test support hardware. For this evaluation, a blanking plate will replace the Suitport Interface Plate. See Figures 4 and 5.

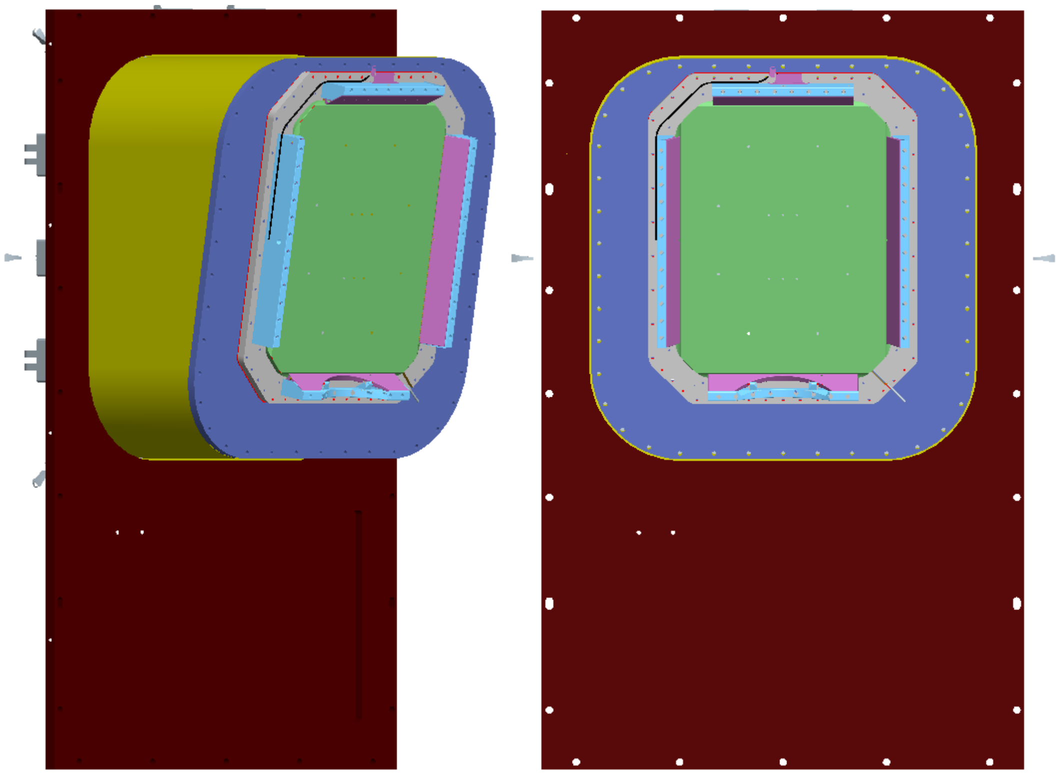


Figure 2 – Chamber B Bulkhead

For the Z-1 Suit Port Test, Manlock B1 will be used as part of the chamber. This will give increased volume and pumping train.

For the Z-1 Suit Port Test, Manlock B2 will be used as a staging area for the test. Personnel will enter the Z-1 suit through back of the suit.

Chamber B manlock pressure control is performed by the Programmable Logic Controller (PLC). The main power distribution is configured to the uninterruptible power supply (UPS). Each manlock is provided with a dedicated control panel located in front of each manlock exterior. The control panel provides auto depress/repress and emergency repress modes.

For the Z-1 Suit Port Test Manlock B2 will be pressurized to 6.2 psig and the chamber will be at atmospheric.

Figure 3 illustrates Manlock B1 control panel.

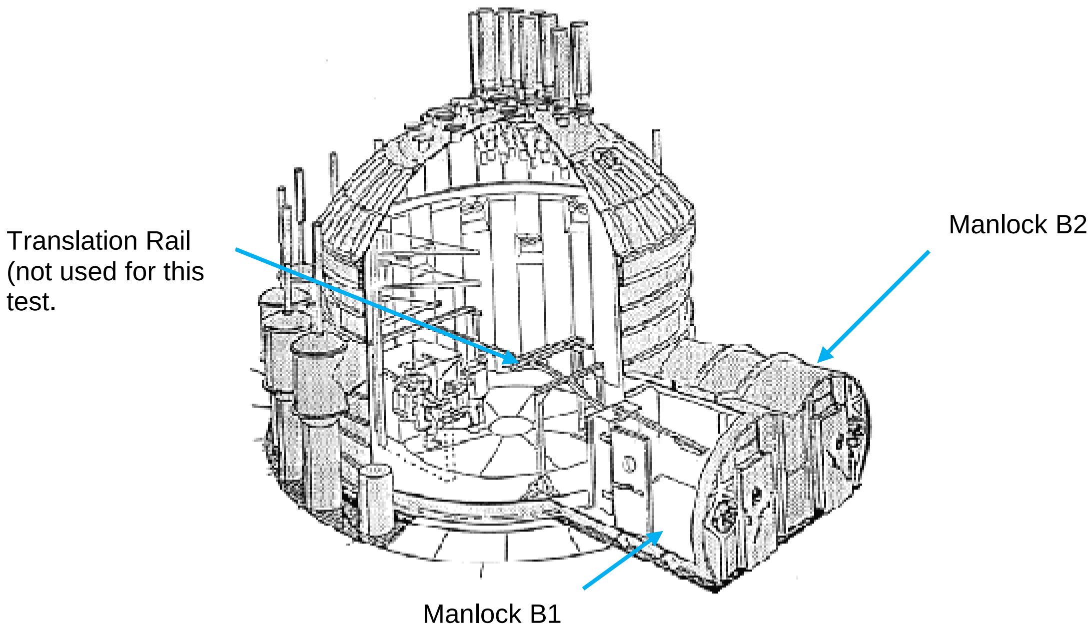


Figure 3 – Chamber B Cutaway w/o the Z – 1 Suit

7.2 Test Article (Pneumatic Flipper) Configuration

The pneumatic flipper suit port hardware and ancillary support equipment provide the necessary functions and interfaces to conduct manned pressurized suit operations when combined with (a) a suitable gas supply system, (b) cooling water supply and (c) suitable communication system.

7.2.1 Pneumatic Flipper Suitport (PFS)

The Pneumatic Flipper Suitport (PFS) secures the Suitport Interface Plate (SIP) using four spring-assisted flippers that are located along the top, bottom, and both sides of the suitport. The air bags sit between each flipper and the flipper housing. Pressurizing the air bags overcomes the spring force that keeps the flippers in the dock position and the flippers rotate, like a hinge, to the undock position. When the air in the bags is vented to the ambient environment, the spring loaded flippers return to the docked position. The PFS uses an inflatable seal to maintain isolation between the habitable volume and ambient environment. The inflatable seal is depressurized prior to undocking and pressurized after docking.

7.2.1.1 Hardware Instrumentation

The Pneumatic Flipper Suitport will be instrumented with two temperature sensors and five strain gauges. Additionally, the blanking plate will be instrumented with two strain gauges. Temperature sensors measure between +60°F and +100°F, have a minimum accuracy of ±3.0°F, and will be logged at a frequency of 1Hz. Strain Gauges have a minimum accuracy of ±0.5% and will be logged at a frequency of 1 to 500 Hz, depending on the task. General locations for the temperature sensors and strain gauges are shown in Figures 4 and 5.

7.3 Test Article (Space Suit) Configuration

The Z-1 suit hardware and ancillary support equipment provide the necessary functions and interfaces to conduct manned pressurized suit operations when combined with (a) a suitable gas supply system, (b) cooling water supply and (c) suitable communication system.

The various Z-1 suit pressures are as follows:

Table 3 – Z – 1 Suit Parameters

Suit	Operational Pressure Range	Structural Pressure	Proof Pressure	MAWP
Z-1	0 – 8.3 (± 0.5) psid	1.5 x specified test pressure	17.6 psid	15.8 psid

The operational pressure range is the range to which the suit can be nominally operated for manned testing. The top end of the nominal operational pressure range is equivalent to 1/2 the proof pressure. Structural pressure is 1.5 times the specified test pressure for any given test. Proof pressure is the maximum unmanned pressure to which the suit was tested by the vendor prior to delivery. The maximum allowable working pressure (MAWP) is 90% of the proof pressure. The pressure systems RVs are set to keep components below their MAWPs. If the suit is pressurized over its MAWP, the suit will be taken out of service and an in-depth inspection/review of the suit will be performed before the suit is put back in service.

The Z-1 employs use of a rear-entry door for donning and doffing. The Z-1 suit weighs 126 lbs, however, when including additional test support hardware for this test [Suitport Interface Plate (28 lbs), Chamber B PLSS mock-up (8 lbs)] the total on-back mass when wearing the Z-1 is 162 lbs.

7.3.1 Capabilities

The Z-1 suit and associated support equipment provides the crewmember or test subject with the following:

a) Anthropomorphic pressure enclosure (enclosure includes attachments and openings for breathing gas supply system interface).
b) Liquid cooling circuit (with attachments and openings for liquid cooling supply circuit interface).
c) Communication system interface.

7.3.2 External Interfaces

The Z-1 suit has three main external interfaces: breathing gas, cooling water, and a communications system.

7.3.2.1 Breathing Gas

The Z-1 suit is designed to receive certified breathing air at 5 – 6 ACFM (actual cubic feet per minute) to both inflate the pressure garment and provide a breathable atmosphere for the suit subject. The breathing air is delivered to the pressure garment via a certified gaseous breathing air system. The air enters the pressure garment at the connection located on the rear entry door (‘Air In’) and is routed into the helmet. The return air (exhalent) is removed from the suit at the ‘Air Out’ connection also on the rear-entry door. Both connectors are Apollo-style air connectors.

Figure 4 – Pneumatic Flipper System with Blanking Plate Installed

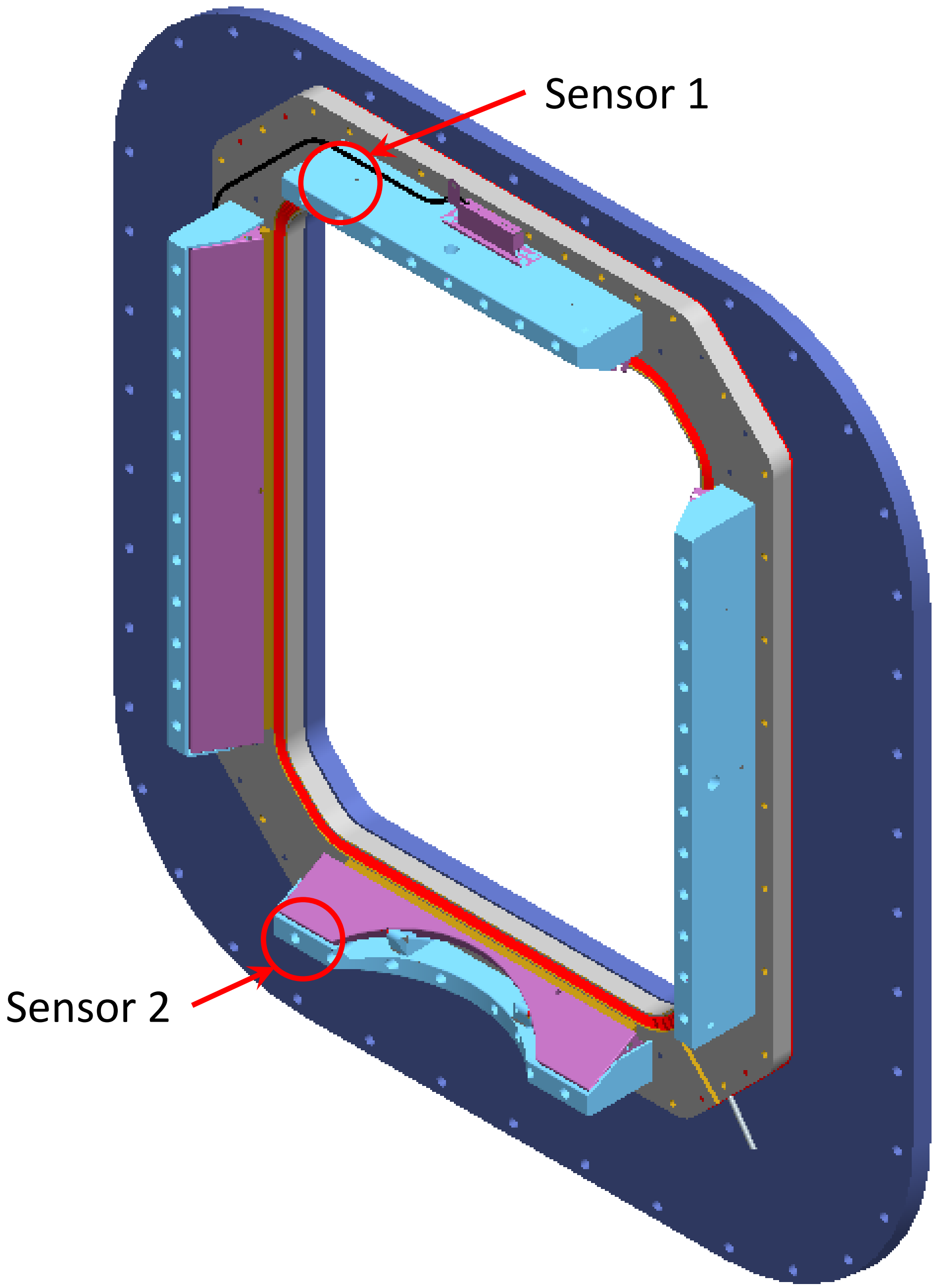


Figure 5 – Temperature Sensor Locations

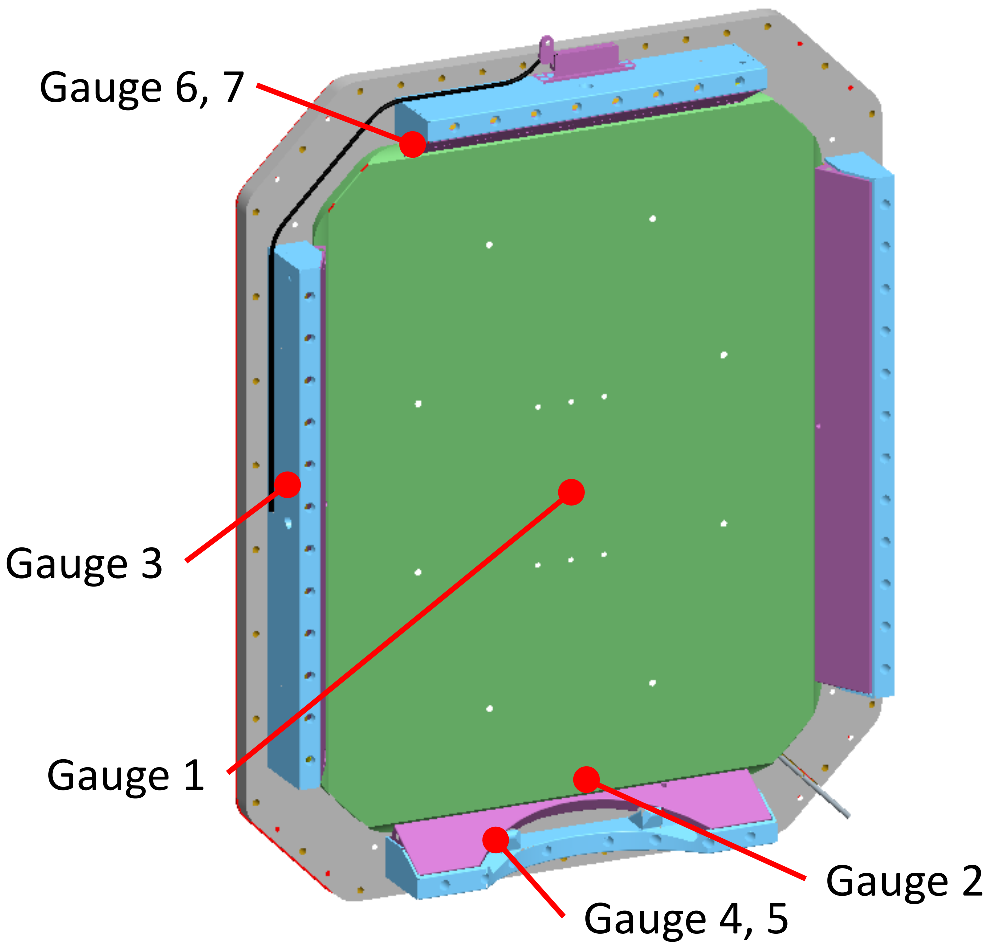


Figure 6 –Strain Gauge Locations

Figure 7 – Close-up of Pneumatic Flipper System (PFS)

7.3.2.2 Communications

The Z-1 suit contains its own internal communications system to receive and deliver audio from and to the suit test team. The in-suit speakers, attenuator, amplifier box, and associated wiring are housed behind a protective cover in the hatch. A hard mounted microphone system resides along the suit-side neck ring to

provide off-human communications. The internal communications set-up also allows for connection of a more traditional communications carrier assembly (CCA) as well when head-borne systems are requested for evaluation. The internal system connects to one of three external communications systems that actually provide the system power and signal processing via a Bendix connector on the suit rear hatch. The location of these connections and their internal routing is shown in Figure 3.

The Space Suit Audio Communication Interface System (SPACIS) is the primary external comm. interface for space suit testing. The Z-1 suit is approved for use with both SPACIS I and II. Configuration of the SPACIS and associated communication hardware is documented in CTSD-ADV-819: *Hazard Analysis for Spacesuit Audio Communication Interface System*. The SPACIS system has a line level speaker output and is designed to interact with either the single-channel or the four-channel amplifiers. The microphone input is designed for 600 Hz electrical microphones. Technicians and operators primarily connect to SPACIS utilizing the RSwo-601 belt packs. In lab environments, the external speaker can be used to broadcast two-way comm. to the entire test team real-time. The suit is connected utilizing a communication line that runs underneath the breathing air and cooling umbilical sheath.

The Advanced EVA (AEVA) Communications System is an alternate communication system is a wireless cable-free; battery operated portable system that is integrated into the Liquid Air Backpack. This system is used where cable free operations are required, such as the rock yard or other remote field locations. A complete description of this system and a specific configuration description can be found in CTSD-ADV-563: *AEVA Communications System Hazard Analysis Report.*

Figure 8 – Z – 1 hatch connections and line routing for air, water, and comm.

7.3.3 Physical Description

The prototype Z-1 suit is commonly described as a “soft” planetary exploration suit. The ‘soft’ is a bit of a misnomer because the suit actually contains several hard mobility elements; the term ‘soft’ is intended to convey the idea that the primary structures of the suit are pliable fabrics when unpressurized. The bearings in the suit are custom made for space suit applications by Airlock, Inc. The bearings are encased in housings

that allow the bearings to be incorporated into the suit via flange mountings. All of the bearings have a lip-type seal. The Z-1 suit consists of the following assemblies, which are described in detail in the following paragraphs:

- Pressure Garment Upper Torso Assembly
- Pressure Garment Lower Torso Assembly
- Glove Assembly
- Boot Assembly
- Ancillary Support Equipment

7.3.3.1 Pressure Garment Upper Torso Assembly

There is only one approved configuration of upper torso for the Z-1 suit. This upper torso assembly is comprised of the helmet, suit-side helmet disconnect, rear entry hatch subassembly, shoulder subassembly, lower arm subassembly, soft upper torso, and the optional Suit port Interface Plate (SIP).

7.3.3.1.1 SHOULDER

The Z-1 shoulder assembly consists of a three bearing soft shoulder joint that incorporates a single axis joint between the scye and mid shoulder bearings. The restraint is fabricated with six-ounce polyester material and incorporates circumferential Spectra restraint webbings and Vectran braided cord axial restraint lines. The bladder is a urethane film. The scye and mid-shoulder bearings are titanium 6AL-4V; the upper arm bearing is stainless steel 17-4.

The shoulder soft goods interface with the scye bearing on one end and upper arm bearing on the other. The axial restraints are attached to these bearing housings via brackets and the soft goods are flange mounted, using the same methods currently used in the Shuttle Extravehicular Mobility Unit (EMU).

7.3.3.1.2 ELBOW

The elbow joints are based on the Shuttle Space Suit Assembly (SSA) enhanced elbow and knee single axis patterned gore restraint design. The joints are fabricated with six-ounce polyester and ½ inch Spectra primary axial restraint webbings. The elbow is constructed with the conventionally used patterned, heat sealed urethane-coated bladder cloth.

The arm length is adjusted into any one of three positions by adjusting the arm axial restraint length via its mounting bracket, while the base fabric is sized through the use BOA and cord assembly for a total of 1 ¼ inches of adjustment.

7.3.3.1.3 HELMET

The Z-1 can be configured with two different helmets: a 13 inch or 14 inch diameter hemispherical dome originally designed for the MK-III prototype space suit. Both helmets consist of a detachable, transparent hard pressure vessel encompassing the head and include the passive disconnect for attachment to the upper torso with an Ortman wire fitting.

7.3.3.1.4 SOFT UPPER TORSO

The soft upper torso (SUT), constructed of a restraint of six-ounce polyester and a urethane coated fabric bladder, interfaces with the waist bearing flange, the shoulder bearings, a rear entry hatch subassembly, the optional SIP, and the helmet neck ring. The SUT also incorporates an internal harness system to index the wearer to the suit.

The hatch subassembly has two main components: the hatch ring and hatch door. The hatch ring is flange mounted to the SUT structure in a manner similar to the BSC mounting on the Shuttle EMU waist soft goods. The locking mechanism for securing the hatch to the HUT is a breech lock design with the locking lever located in front of the suit just above the helmet (behind the right ear). The hatch door is an aluminum frame with fabric-filled cutouts for weight reduction. It has four threaded bosses facing away from the suit that enable the attachment of the Liquid (or Portable) Air Backpack and weight off-load systems. The top third of the hatch door is aluminum as well and provides the structure for consumables pass-thru and one additional pass-thru that can be utilized to meet test specific needs.

The SIP is a 3/4" thick 6061 aluminum plate. The SIP is flange mounted along the hatch ring to SUT interface for suit port testing and provides a pressure-sealing surface for the suit-to-suitport interface for delta pressures operations.

7.3.3.2 Pressure Garment Lower Torso Assembly

The lower torso assembly is comprised of three basic subassemblies: waist, brief-hip, and lower leg.

7.3.3.2.1 WAIST

The Z-1 waist joint is comprised of three elements- rotational joint, flexion/extension joint, and adduction/abduction joint- that can be stacked in any order. The rotational joint is achieved by incorporating the original MK-III large profile waist bearing into the design. The waist bearing can be locked out by inserting a pip pin across the upper and lower races. The ad/ab and flex/ex joints are patterned convolutes separated by titanium shape control rings. The joints are fabricated with six-ounce polyester material and circumferential Spectra restraint webbings. The bladder is a patterned heat-sealed urethane film. The waist of the suit may be sized to any one of three positions by adjusting the waist axial restraint length via brackets mounted on the upper and lower waist rings. The waist base restraint length is managed using a zipper assembly.

It is operationally acceptable to use the suit without any of the waist elements in order to accommodate subjects of short stature; however, the mobility of the suit decreases with each joint element removed. For this configuration, the SUT and LTA flange mount directly to a shape control ring.

The waist utilizes braided Vectran cord primary axial restraints, which are stabilized with Teflon spools. There are three sizes of the axial restraint lines, which provide three inches of torso length sizing. The axial restraint lines are anchored to the body seal closure and the waist control ring with brackets. The waist also incorporates Spectra webbing secondary axial restraints.

7.3.3.2.2 BRIEF-HIP

The brief of the Z-1 serves as an anthropometrical transition from the waist joint to the hip/thigh joint. A sixteen-inch major diameter elliptical shape control ring is located between the waist and brief to maintain the elliptical profile, which is preferred anthropometrically in the torso. A soft elliptical patterned brief constructed of six-ounce polyester and a Spectra crotch restraint webbing transitions to the 10.3-inch diameter leg openings. The bladder is patterned, heat-sealed film. The Hip/Thigh joint is a two bearing design with a soft goods transition element. The first bearing interfaces via a flange mount with the brief leg openings on acute horizontal and vertical angles. The second bearing interfaces with the leg on a flat horizontal via a flange mount. The soft goods transition element runs between the two bearings. The soft goods incorporate, just above the hip/thigh to leg interface, a single axis, patterned convolute joint to allow leg adduction/abduction. Spectra webbing axial restraints are mounted to the bearings with brackets. Both hip bearings can be locked out by inserting two screws between the upper and lower races of each bearing.

7.3.3.2.3 LOWER LEG

As with the elbow, the knee joints are based on the Shuttle Space Suit Assembly (SSA) enhanced knee single axis patterned gore restraint design. The joints are fabricated with six-ounce polyester and ½ inch Spectra primary axial restraint webbings. The knees are constructed with the more conventionally used patterned, heat-sealed urethane-coated bladder cloth. The axial restraint lengths of the legs are adjusted by using any one of four axial restraint loops on the lower leg and changed via the mounting bracket.

The ankle joint has a patterned convolute restraint of six-ounce polyester and a patterned, heat-sealed cloth bladder. The braided Vectran cord axial restraints, rather than the being stitched down or running through spools as on the waist, are indexed to the convolutes via webbings. The axial restraints interface with the leg and boot via restraint brackets.

7.3.3.3 Glove Assembly:

The Z-1 lower arm-to-glove interface is a Shuttle Extravehicular Mobility Unit (EMU) style suit side wrist disconnect. The Z-1 suit can be used with any approved glove configurations which interface with this wrist disconnect. Any gloves used with the Z-1 Suit shall have a MAWP of at least 7.2 psid for 4.3 psid operations or 15.8 psid for 8.3 psid operations.

7.3.3.4 Boot Assembly:

There are two approved boot configurations for the Z-1 lower torso (REI Adjustable Boot Assembly and David Clark Boot).

7.3.3.4.1 REI Adjustable Boot Assembly

The REI boot (available in men's size 9, 11, or 13) is a modified commercial boot. The abbreviated boot upper retains the steel toe and heel stiffener features of the commercial boot. The leg axial restraint lines interface to the boot on either side of the instep via an aluminum bracket. A one-piece aluminum bracket with stainless steel pins in the instep and a steel mid-sole and fiberglass shank in the outsole were incorporated as reinforcements, which were required to carry the load of leg axial restraints. The original REI boot design was further modified to be self-adjustable while at pressure. The boot uses a commercial-off-the-shelf (COTS) Boa™ device for instep sizing and can be worn with or without one of two different modified COTS booties for indexing the foot within the boot. The boot uses an adapter ring to allow it to interface with the Mark III ankle bearing. The REI Adjustable Boot Assembly has a MAWP of 15.8 psid and is approved for use at operating pressures up to 8.3 psid.

7.3.3.4.2 David Clark Boot

The David Clark Boot assembly has a Gore-Tex bladder with a 400-denier Nomex upper, which incorporates patterned, convolutes for flexion/extension. The boot assembly has an instep strap for indexing the foot and a standard work boot sole. The David Clark Boot has a MAWP of 7.2 psid and is therefore only approved for use during 4.3 psid operations.

Both types of boots connect to the Z-1 lower leg via an Ortman wire to the MK-III style ankle bearing which is flange mounted to the boot disconnect.

7.3.3.5 Ancillary Support Equipment

7.3.3.5.1 Liquid Cooling Garment (LCG):

A modified Shuttle LCVG is used with the Z-1 Suit. It is a conformal garment, which is worn whenever the suit is worn. It has ethylene vinyl acetate tubing, woven through the spandex restraint cloth. Cooling water circulates through the tubing, near the skin. The modifications from its original configuration were removal of ventilation lines/plenum and switching from the large Multiple Water Connector to commercially available CPC connectors for the water line interface.

7.3.3.5.2 Thermal Comfort Undergarment (TCU):

The TCU is a two-piece (top and bottom) crew optional underclothing. The TCU is worn under the LCG to improve crew comfort and hygiene.

7.3.3.5.3 Polar Heart Rate Monitor/Zepher Bioharness

The Polar Hearth Rate Monitor may be worn during suited testing to monitor the test subject's heart rate. The Zepher Bioharness may also be worn during suited testing. The Zephyr Bioharness is a sensor strap with a transmitter and data logging memory capability used for physiological monitoring. The Zephyr records heart rate, breathing, posture (attitude of device in degrees from vertical), skin temperature, and activity and has a transmit range up to 100 m (50 feet), environment and antenna dependent.

7.3.3.5.4 Pneumatic Flipper Suitport (PFS)

The Pneumatic Flipper Suitport (PFS) secures the Suitport Interface Plate (SIP) using four spring-assisted flippers that are located along the top, bottom, and both sides of the suitport. The air bags sit between each flipper and the outer frame. Pressurizing the air bags overcomes the spring force that keeps the flippers in the dock position and the flippers rotate, like a hinge, to the undock position. When the air in the bags is vented to the ambient environment, the spring loaded flippers return to the docked position. The PFS uses an inflatable seal to maintain isolation between the habitable volume and ambient environment. The inflatable seal is depressurized prior to undocking and pressurized after docking.

7.3.3.5.4.1 Hardware Instrumentation

The Pneumatic Flipper Suitport will be instrumented with two temperature sensors and five strain gauges. Additionally, the blanking plate will be instrumented with two strain gauges. Temperature sensors measure between +60°F and +100°F, have a minimum accuracy of ±3.0°F, and will be logged at a frequency of 1Hz. Strain Gauges have a minimum accuracy of ±0.5% and will be logged at a frequency of 1 to 500 Hz, depending on the task. General locations for the temperature sensors and strain gauges are shown in Figures 4 and 5.

7.3.4 Test Description

7.3.4.1 Test Environment

To evaluate the Suitport at operating pressure, the Main Chamber pressure will be reduced to 6.4 psia (approximately 335 torr). The Main Chamber pressure will be further reduced to 2.2 psia to provide the pressure differential required for proof loading. The chamber temperature will remain unconditioned.

7.3.4.2 Test

A test run will begin with the execution of pretest checklists followed by the Chamber B Inspection and Seal Pretest Checklist. After all checks are complete, the Manlock B1 Outer Door, Manlock Interconnect Door, and Vestibule Door are closed and the Chamber, Manlock, Vestibule, and Suitport seal are depressurized. Upon reaching the specified pressure, the vestibule will be isolated and the suitport inflatable seal pressurized. Seal and vestibule pressures will be monitored and a leak rate calculated. After the seal leak check, the vestibule will be equalized with the manlock and the inflatable seal pressure increased. Vestibule pressure will be monitored and a leak rate calculated. The vestibule door will be opened after the leak check and the seal inspected. The vestibule door will then be closed. The vestibule pressure will be equalized with the main chamber prior to venting the pressure in the inflatable seal. The pneumatic flippers may be cycled prior to repressurizing the main chamber. The evaluation described above will be performed at chamber pressures of 6.4 psia and 2.2 psia.

Once testing is completed for the day, post test checklists will be performed to shutdown facility systems.

8.0 Unique Material/Chemical Use

	Material/Chemical Name	Quantity Used	Approval Method
1	N/A		

Figure 9 -- Chamber B Manlock Control Panel

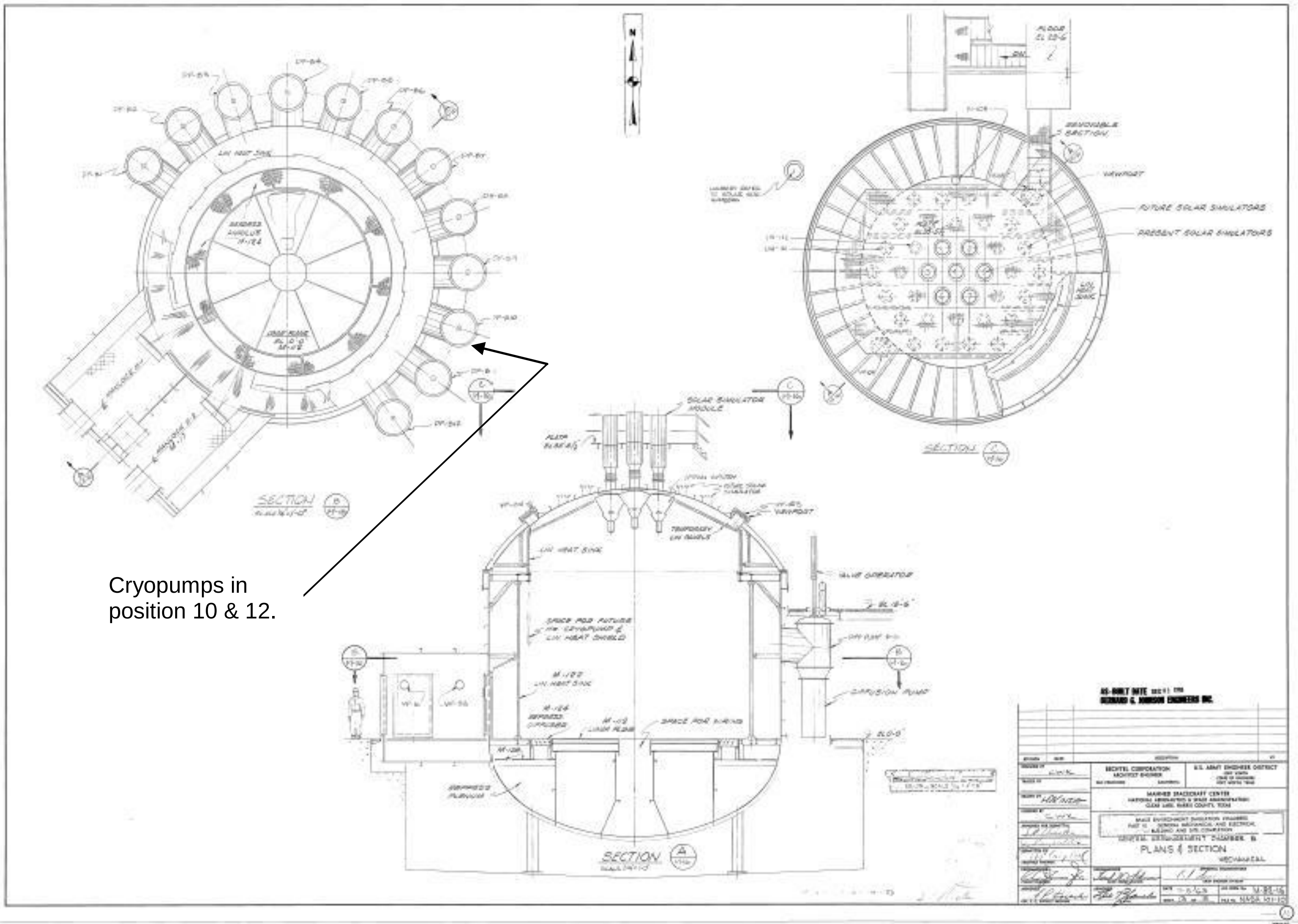


Figure 10 – Cross Sectional View of Chamber B

Figure 11 – View of Chamber B Manlocks

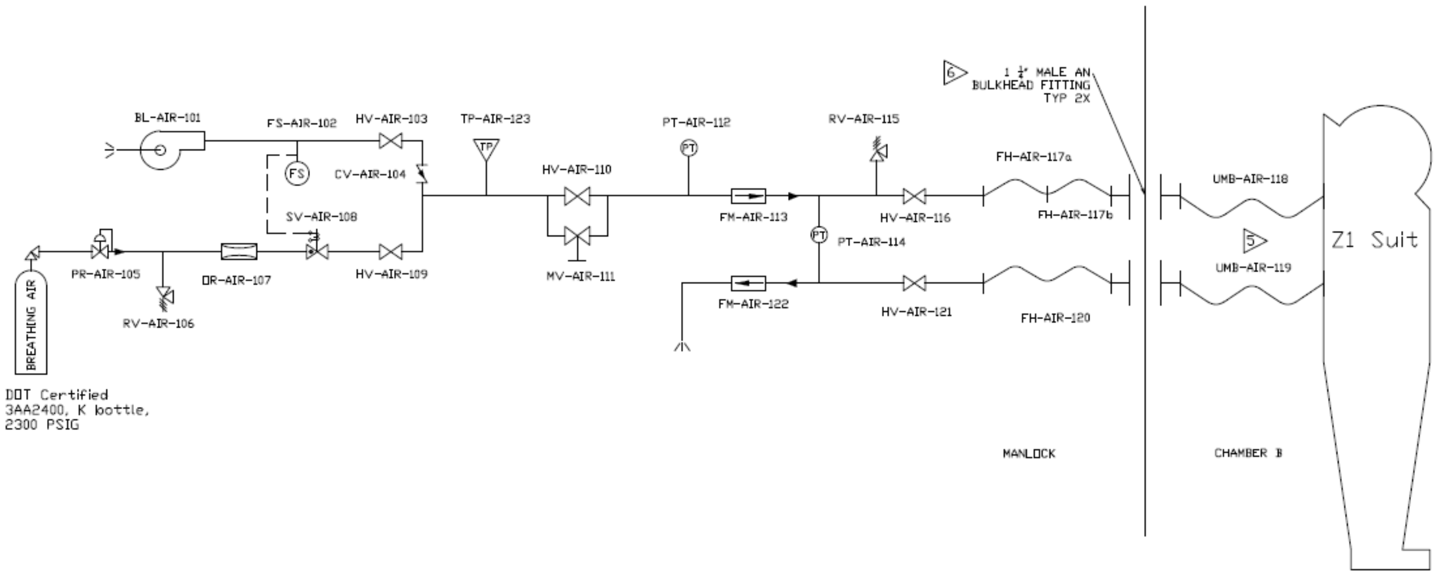


Figure 12 – Breathing Air System

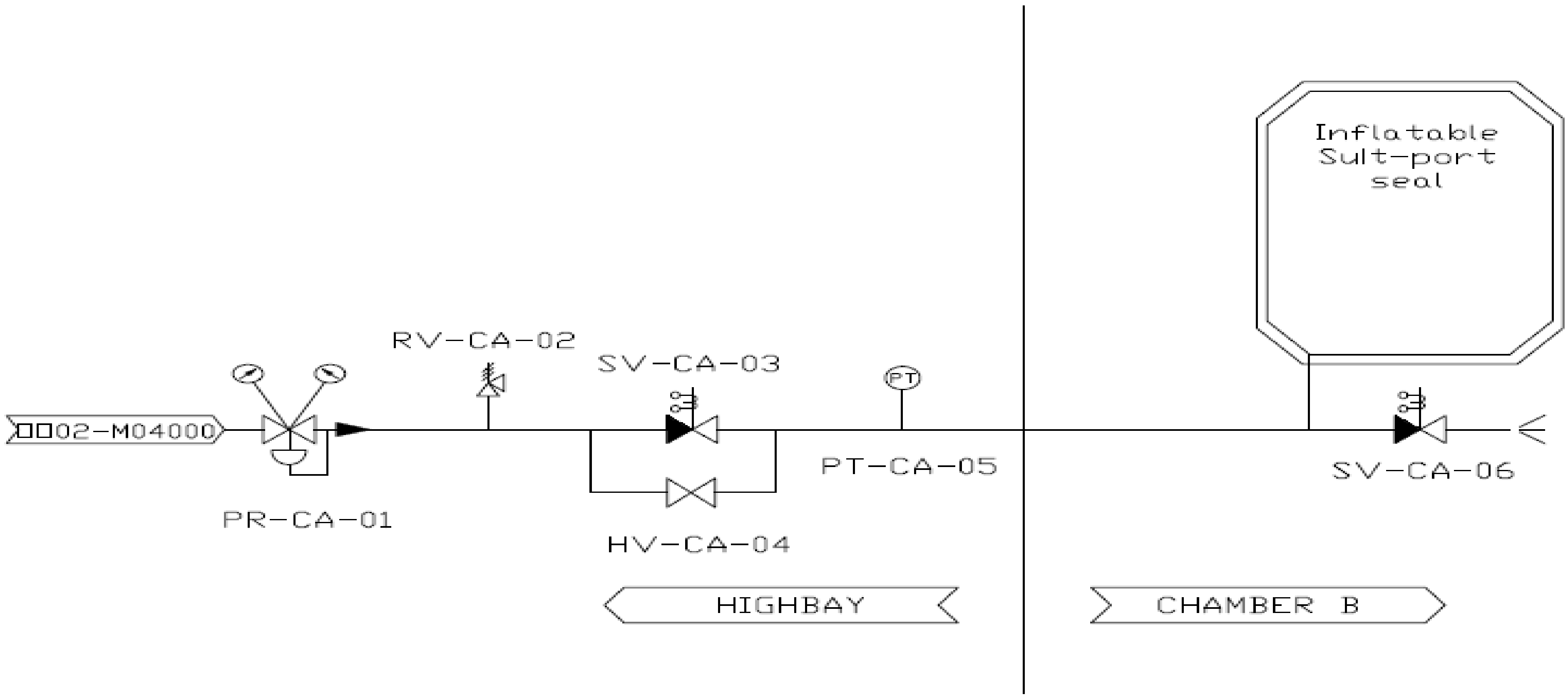


Figure 13 – Suit Port Inflatable Seal Air Supply

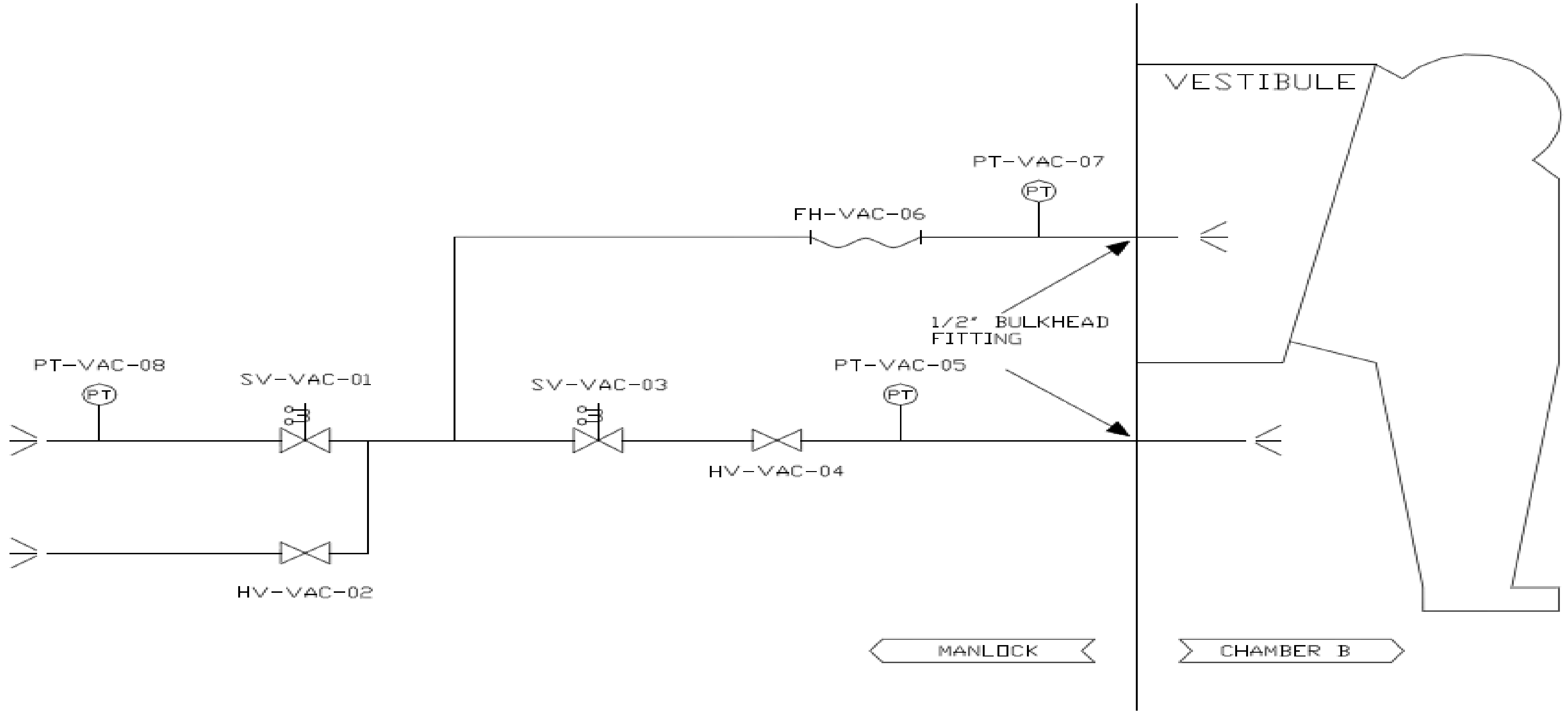


Figure 14 – Vestibule Equalization

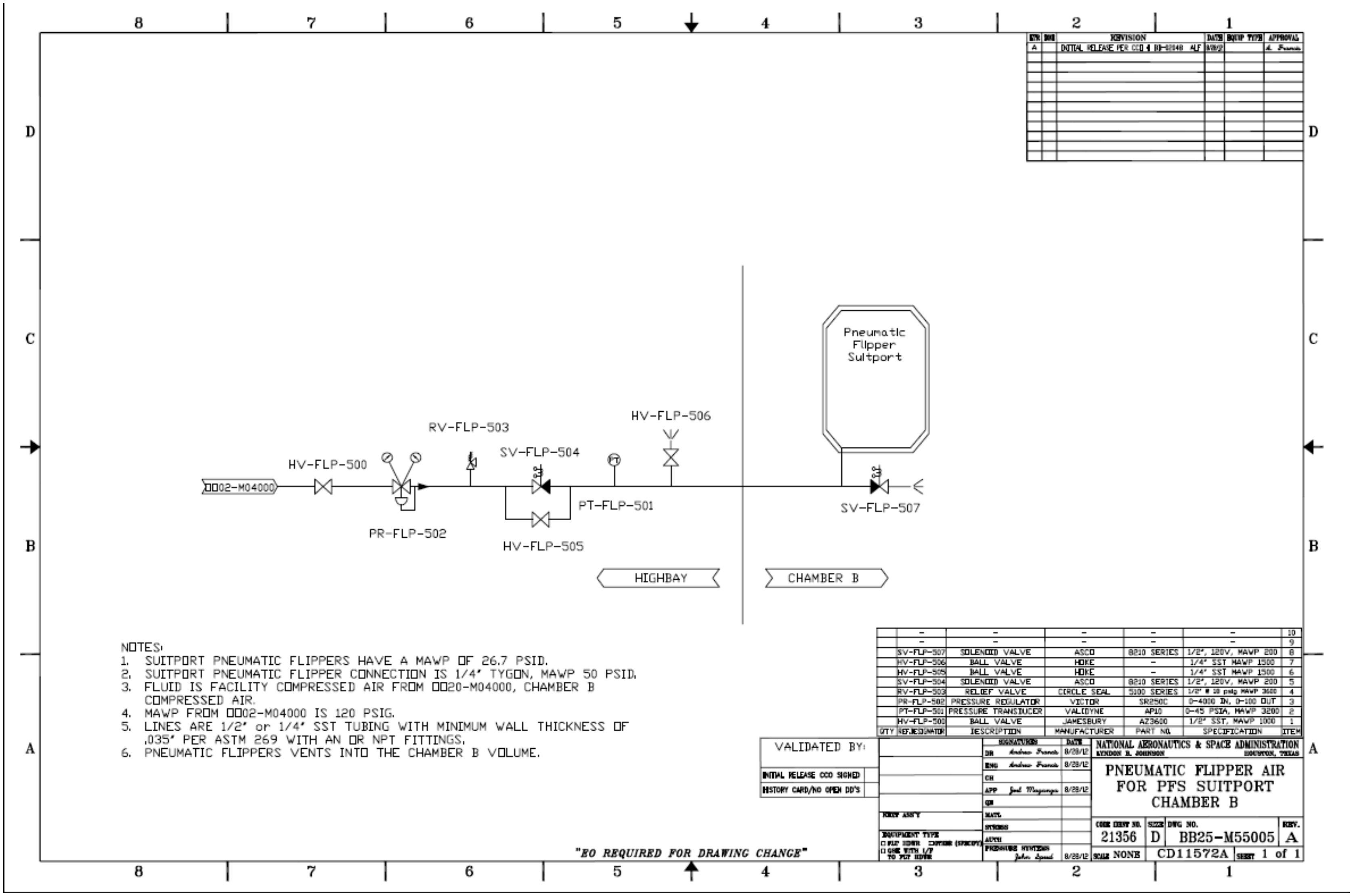


Figure 15 – Pneumatic Flipper Air for PFS Suitport Chamber B

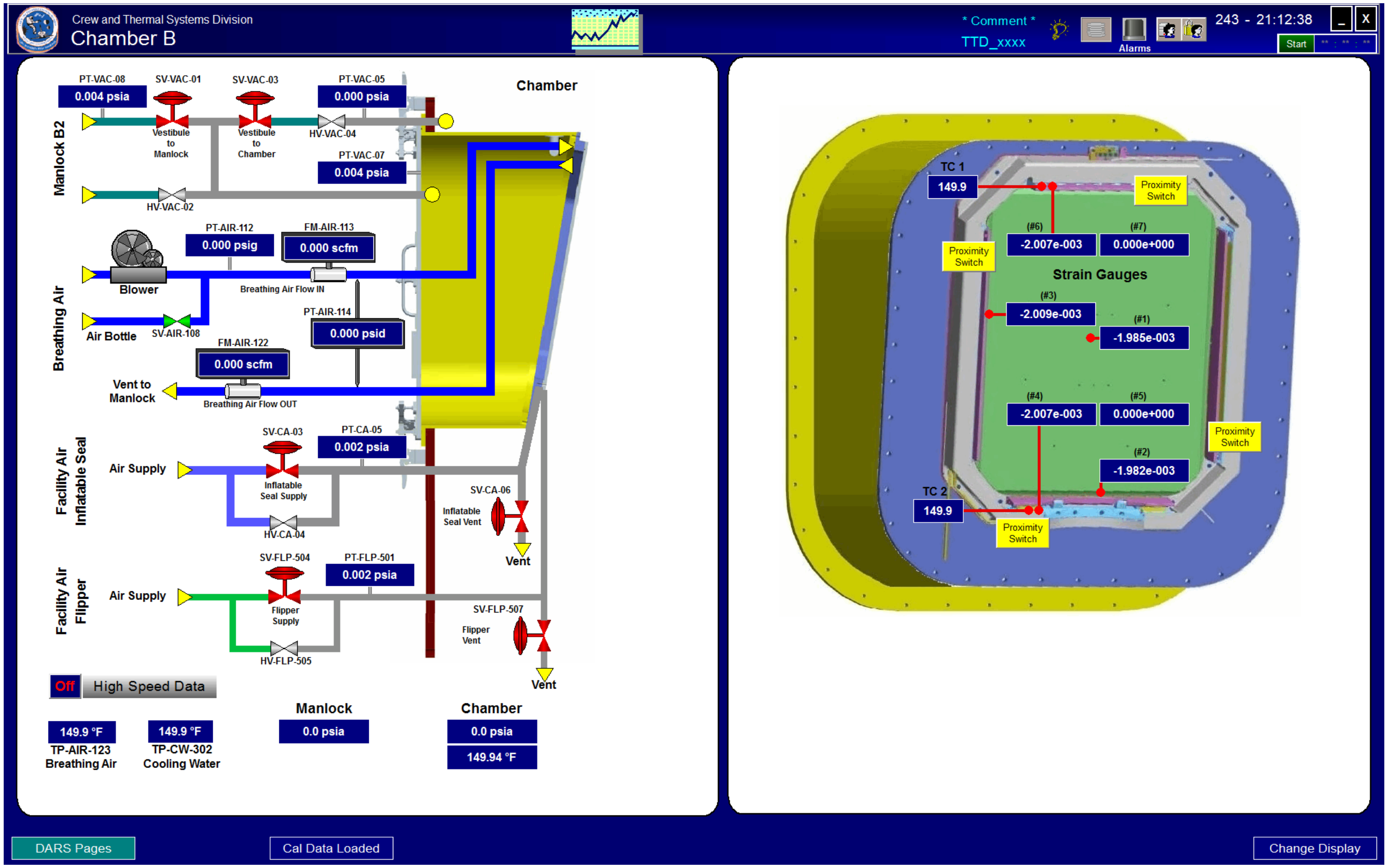


Figure 16 – Chamber B Pneumatic Flipper Suit Port Main Data Screen

9.0 Hazard Summary

Table 3 summarizes the potential system hazards and risk assessment codes associated with this facility equipment, hardware, task, and/or test system. The details of each hazard, such as the specific hazard causes, controls and verifications, are documented on the hazard analysis work sheets in Appendix A.

Table 4 – Hazard Summary Table

Hazard		Consequence/Likelihood/RAC	
		Before Controls	After Controls
1	Contact with Exposed Electrical Energy	I/B/1	I/E/4
2	Fire	I/B/1	I/E/4
3	Inadvertent Chamber Depressurization	I/C/2	I/E/4
4	Oxygen Deficient Atmosphere	I/B/1	I/E/4
5	Personnel Falling	I/B/1	I/D/3
6	Loss of PLC	I/B/1	I/E/4
7	Loss of Depress/Repress Control	I/B/1	I/E/4
8	Loss of Electrical Power	I/B/1	I/E/4
9	Manlock Control Valve Failure	I/B/1	I/E/4
10	Personnel Struck by Manlock Door	III/A/2	III/D/5
11	Contamination	I/B/1	I/E/4
12	Sharp Edges/Corners & Pinch Points	III/B/3	III/D/5
13	Structural Failure	I/B/1	I/E/4
14	Impact/Collision	II/B/2	II/D/4
15	Contact With or Inhalation of Toxic Substances	II/A/1	II/E/5
16	Accidental Flipper Mechanism Release	I/B/1	I/E/4
17	Ignition Source in Test Area Results in Facility Fire and Personnel Injury or Equipment Damage	I/B/1	I/E/4
18	Loss of Breathing Air Supply to the Test Subject	I/B/1	I/D/3
19	Pressure System Rupture When Pressurizing the Z1 Suit	I/A/1	I/D/3
20	Electrical Shock in the Z-1 Suit	III/A/2	III/D/5
21	Umbilical Retractor Failure	II/A/1	II/D/4
22	Loss of Cooling Supply to the Test Subject	III/A/2	III/D/5
23	Emergency Rescue Impeded	I/B/1	I/D/3

Hazard		Consequence/Likelihood/RAC	
		Before Controls	**After Controls**
24	Rapid Suit Depressurization	I/B/1	I/D/3
25	Improper Suit Fit	III/B/3	III/D/5
26	Aspiration of Vomit	I/C/2	I/E/4
27	Muscle Cramps or Exhaust	III/A/2	III/D/5
28	Subject Entrapment	III/B/3	III/E/6
29	Hyperventilation	III/B/3	III/D/5
30	Loss of Two Way Verbal Communications	III/B/3	III/D/5

Appendix A. Hazard Analysis Worksheets

A.1 Hazard Analysis Worksheet – Contact With Exposed Electrical Energy

Hazard Title: **CONTACT WITH EXPOSED ELECTRICAL ENERGY**			**HAWS No.** 1
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:

Personnel come in contact with exposed electrical wiring, terminals, or components with enough energy to cause, pain, injury, or death. Discharge of electrical energy with sufficient energy to cause damage to equipment or facility. Electrocution or other injury due to contact with exposed electrical energy greater than 50 vdc with greater than 8.5 milliamps current.

Hazard Causes:

1. Contact with exposed or bare electrical wiring while it is greater than 50 Vdc @ greater than 8.5 milliamps causing injury and/or death.
2. Contact with exposed or bare terminal connectors while they are energized to greater than 50 Vdc @ greater than 8.5 milliamps causing injury and/or death.
3. Inadvertent activation of electrical systems during maintenance causing equipment damage, injury, and/or death to personnel.
4. Improper grounding of the circuit causing flow of energy through other than planned pathways causing damage to equipment, injury, and/or death to personnel.

Hazard Controls:

1.1 All electrical circuits are designed in accordance with Paragraph 4.6 of STB-F-361 to assure that exposed or bare electrical circuits are not present.
1.2 All electrical components were chosen to reduce exposure to electrical wiring at all times.
1.3 PLCs are designed so that the electrical wiring is internal to the controller.
1.4 Electrical circuits and wiring during normal operations are enclosed inside PLC cabinets and conduits respectively.
1.5 All high voltage is located in the MCC and not accessible by ESCG personnel.
1.6 Voltages present in the PLC cabinets are below 120 Vac.
1.7 Only authorized electrical technicians meeting the requirements of STB-F-621, paragraph 6.0 perform electrical work and installation on electrical systems
1.8 All wiring is insulated IAW the requirements for insulated conductors as called out in the NEC and STB-F-361.
1.9 All wiring is enclosed in electrical conduits or cable trays that are not accessible from the floor levels in each area IAW STB-F-361.
2.1 All terminal strips are designed to enclose the wire ends so that wiring is not accessible to contact by personnel.
2.2 All power cabling coming into the cabinets from the MCCs are covered with Lexan covers, which prevent contact by personnel.
2.3 Only authorized electrical technicians meeting the requirements of STB-F-621, paragraph 6.0 perform electrical work and installation on electrical systems.
3.1 Lockout/Tagout procedures in accordance with CTSD-SH-1447A & CTSD-SH-1448 are used when working with potentially energized circuits.
3.2 Only authorized electrical technicians meeting the requirements of STB-F-621, paragraph 6.0 perform electrical work and installation on electrical systems
4.1 All circuits are grounded in accordance with article 250 of the NEC and STB-F-361.
4.2 All operations on electrical systems are performed under LOTO.
4.3 Only authorized electrical technicians meeting the requirements of STB-F-621, paragraph 6.0 perform electrical work and installation on electrical systems.
4.4 When activity is performed in proximity of energized electrical circuits (such as calibration), only trained personnel with personal protective equipment (PPE) (such as rubber mat and gloves, etc.) as called out in STB-F-621 are allowed to perform such activity

Hazard Title: CONTACT WITH EXPOSED ELECTRICAL ENERGY			HAWS No. 1
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Control Verifications:

1.1.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level to assure that electrical circuits do not allow for access to exposed wiring.

1.1.2 Inspection of the installation to assure that the circuits have been installed per the drawings and recorded on a TPS.

1.2.1 Review of drawings to assure that electrical components prevent contact with contact with electrical components in accordance with NEC. Electrical wiring is insulated per the requirements of Paragraph 4.6 of STB-F-361.at the PDR & CDR level.

1.2.2 Inspection of the installation to assure that the circuits have been installed per the drawings and recorded on a TPS.

1.3.1 See Allen-Bradley PLC cut sheet.

1.4.1 Inspection of the installation to assure that the circuits have been installed per the drawings and recorded on a TPS.

1.5.1 Inspection of the circuits to assure that high voltage is not present in the PLC cabinets and documented on a TPS.

1.6.1 Inspection of the circuits to assure that high voltage is not present in the PLC cabinets and documented on a TPS.

1.7.1 Review of personnel training records to assure that electrical technicians are qualified to perform the desired task.

1.8.1 Inspection of the electrical wiring during installation to verify correct insulation.

1.9.1 Inspection of the wiring to ensure that it is run in conduit or cable trays.

2.1.1 Inspect the components to assure that contact with wiring or circuits are not possible and documented on a TPS.

2.2.1 Review of drawings to assure that all power wiring coming into the PLC cabinets are covered with Lexan covers which prevents contact with electrical wiring or terminals at the PDR & CDR level.

2.2.2 Inspection of the installation to verify all power wiring coming into the PLC cabinets are covered with Lexan covers which prevents contact with electrical wiring or terminals on a TPS.

2.3.1 Review of personnel training records to assure that electrical technicians are qualified to perform the desired task.

3.1.1 Review of SPAs and procedures to assure that LOTO is called out.

3.2.1 See personal certifications for installation technicians to assure that installation personal have been trained in LOTO.

4.1.1 Review of drawings to assure that electrical grounding is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.

4.1.2 Inspection of the installation to verify that circuits are properly grounded in accordance with Paragraph 4.6 of STB-F-361 documented on a TPS.

4.2.1 See personal certifications for installation technicians to assure that installation personal have been trained in LOTO.

4.3.1 Review the training records of all personnel performing electrical work to assure that they have the proper training for work with electrical circuits.

4.4.1 Review of SPAs and procedures to assure that LOTO and appropriate PPE is called out.

Remarks:

Electrocution or other injury due to contact with exposed electrical energy greater than 50 vdc with greater than 8.5 milliamps current is defined in NASA/SP-2010-3407, Human Integration Design Handbook (HIDH).

Hazard Title: **CONTACT WITH EXPOSED ELECTRICAL ENERGY**				**HAWS No.** 1
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.2 Hazard Analysis Worksheet – Fire

Hazard Title: FIRE				**HAWS No.** 2
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
Fire occurs in the Manlock causing damage to equipment, injury, and/or death to personnel.

Hazard Causes:
1. Oxygen content in excess of 23% by volume causes fire due to contact with materials that are not compatible with oxygen.
2. Electrical fire due to improperly wired electrical circuits or improperly grounded electrical circuits.
3. Use of flammable or combustible liquids with an ignition source present.
4. Use of oxidizers with a flammable material.
5. Faulty electrical installation allowing for arcing or overheating of the wiring in close proximity to flammable or combustible materials.

Hazard Controls:
1.1 Oxygen is not used for these tests. Air for the subject inside the suit is provided by a small fan located outside the chamber. Backup compressed air will be supplied by K-bottles of breathing air. The Materials Utilization Control Board reviewed all materials to assure compatibility with the planned environment. All ignitions sources are reviewed and for possible contact with the flammable or combustible materials to assured that, both an ignition source and the flammable or combustible materials are not present at the same time.
1.2 Manlocks have UV flame detectors that are utilized during manned testing.
1.3 During non-vacuum periods, there is an active fire detection system outside the chamber.
1.4 Cameras are located inside the chamber and inside the manlock to allow for view of the test article.
2.1 All electrical circuits are in accordance with the Paragraph 4.6 of STB-F-361.
2.2 Main power distribution is on circuit breakers. Fuses are provided accordingly
2.3 All electrical circuits are grounded to facility ground
2.4 Electrical components and PLC are COTS. PLC is UL listed
2.5 Manlocks have UV flame detectors that are utilized during manned testing.
2.6 Cameras are located inside the chamber and inside the manlock to allow for view of the test article.
2.7 If electrical circuitry is required where flammable or combustible materials are present, the electrical circuitry meets the requirements of Article 500 of NEC and STB-F-361.
3.1 The Materials Utilization Control Board reviewed all materials to assure compatibility with the planned environment. All ignitions sources are reviewed and for possible contact with the flammable or combustible materials to assured that, both an ignition source and the flammable or combustible materials are not present at the same time.
3.2 If electrical circuitry is required where flammable or combustible materials are present, the electrical circuitry meets the requirements of Article 500 of NEC and STB-F-361.
4.1 The Materials Utilization Control Board reviewed all materials to assure compatibility with the planned environment. All ignitions sources are reviewed and for possible contact with the flammable or combustible materials to assured that, both an ignition source and the flammable or combustible materials are not present at the same time.
4.2 If electrical circuitry is required where oxidizers are used with flammable or combustible materials are present, the electrical circuitry meets the requirements of Article 500 of NEC and STB-F-361.
5.1 If electrical circuitry is required where flammable or combustible materials are present, the electrical circuitry meets the requirements of Article 500 of NEC and STB-F-361.

Hazard Control Verifications:
1.1.1 Review of drawings by the cognizant design engineer to assure that materials are in accordance with STB-

Hazard Title: **FIRE**			**HAWS No.** 2
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

E-001, STB-F-366, STB-E- 083, & JSC 09604 at the PDR & CDR level.

1.1.2 Inspection of the installation to assure that all materials are as called out on the drawings and have been reviewed and documented on a form 1370.

1.2.1 Inspection of the manlocks to assure that UV flame detectors are installed and operational during test, and documented per STB-F-1133.

1.3.1 Fire detection system has a functional test prior to the beginning of each test series. If it is more than one year since the last test, then the functional is tested out again.

1.4.1 Inspection of the installation prior to usage.

2.1.1 Review of drawings by the cognizant design engineer to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.

2.1.2 Inspection of the electrical system to assure that electrical installations are in accordance with Paragraph 4.6 of STB-F-361 documented on a TPS.

2.2.1 Review of drawings by the cognizant design engineer to assure that main power distribution is on circuit breakers and that fuses are in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.

2.2.2 Inspection of the electrical circuits are fused and on circuit breakers in accordance with STB-F-1134.

2.3.1 Review of drawings by the cognizant design engineer to assure that electrical circuits are grounded in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.

2.3.2 Inspection of the electrical circuits to assure that they are grounded in accordance with Paragraph 4.6 of STB-F-361 documented on a TPS.

2.4.1 Review of drawings by the cognizant design engineer to assure that electrical components prevent contact with contact with electrical components in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.

2.4.2 Review of the Allen-Bradley PLC cut sheet.

2.4.3 Fire detection system has a functional test prior to the beginning of each test series. If it is more than one year since the last test, then the functional is tested out again.

2.5.1 Inspection of the manlocks to assure that UV flame detectors are installed documented per STB-F-1133.

2.6.1 Inspection of the installation prior to usage.

2.7.1 Inspection of the installation prior to usage.

3.1.1 Review of drawings by the cognizant design engineer to assure that materials are in accordance with STB-E-001, STB-F-366, STB-E- 083, & JSC 09604 at the PDR & CDR level.

3.1.2 Review of MSDS's to determine flammability of all materials.

3.1.3 Inspection of the manlocks to assure that materials are as called out on the drawings and are compatible and documented on a TPS.

3.2.1 Inspection of the manlocks to assure that UV flame detectors are installed documented per STB-F-1133.

4.1.1 Review of drawings by the cognizant design engineer to assure that materials are in accordance with STB-E-001, STB-F-366, STB-E- 083, & JSC 09604 at the PDR & CDR level.

4.1.2 Inspection of the installation to assure that all materials are as called out on the drawings and have been reviewed and documented on a form 1370.

4.2.1 Inspection of the facility to verify electrical equipment inside the area where flammable or combustible are used, meet the requirements of article 500 of the NEC.

5.1.1 Inspection of the facility to verify electrical equipment inside the area where flammable or combustible are used, meet the requirements of article 500 of the NEC.

Remarks:

Hazard Title: FIRE				**HAWS No.** 2
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.3 Hazard Analysis Worksheet – Inadvertent Chamber Depressurization

Hazard Title: INADVERTENT CHAMBER DEPRESSURIZATION				**HAWS No.** 3
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/C/2	I/E/4	

Hazard Description & Consequence:
Inadvertent decompression in the manlock to lower than atmospheric pressure and/or decompression to hard vacuum when personnel are inside.

Hazard Causes:

1. PLC faults (hardware or software) or Baratron failure
2. Improper operations of manlock control system.

Hazard Controls:

1.1 Acceptance test is performed to certify the manlock control system (hardware and software)
1.2 Multiple instrumentation data displays are available for manlock control operator to view. Operator is required to operate each manlock control system
1.3 Redundant Baratrons are provided in each manlock to prevent PLC from depressurizing manlock to hard vacuum. PLC is designed to compare two Baratron data for consistency. Light will flash on operator control panels and PLC will stop depressing the affected manlock if two Baratron readings are different from each other. Test rules shall address corrective actions in the event of flashing light alert. Joystick control in local mode is available to continue the operation
1.4 Altitude limit switches (one for 18k feet and one for 35k feet) are provided to prevent the manlock B2 from being depressed to hard vacuum for rescue tech protection
1.5 Pre-test checklist shall verify correct software program prior to test
1.6 Manlock control system is designed to be configured to the PLC or to bypass the PLC using joystick for depress/repress controls
1.7 Man trap switch alarms for main chamber and manlocks
1.8 Chamber close-out procedure shall verify no personnel inside manlock prior to closing doors
2.1 Operators shall be trained to operate the system
2.2 Human factor engineering is designed into the operator control panels to enhance the ease of operation. All controls are labeled and operating status indication lights are provided where appropriate. ER control switches have guarded plates to prevent inadvertent activation. Operator control panels are adjustable in a variety of positions.
2.3 Joystick is designed to lock in each position and will not drift after being moved up or down.
2.4 Joystick control in PLC mode will not operate if it is not in the center position when switched to local mode.
2.5 Multiple manlock pressure data displays are provided above and on the side of the operator control panels.
2.6 Altitude limit switches (one for 18k feet and one for 35k feet) are provided to prevent the manlock B2 from being depressed to hard vacuum for rescue tech protection.
2.7 Man trap switch alarms for main chamber and manlocks.
2.8 Chamber closeout procedure shall verify no personnel inside manlock prior to closing doors.

Hazard Control Verifications:

1.1.1 Pre-test checklist is used to verify proper operation of the manlock control software and hardware and documented on STB-F-1196.
1.2.1 Review of drawings BB09-M01000 to assure that controls and displays are present at the TDs console and Operators console.
1.2.2 Inspection of control panels, TD's panel, and documented on BBMU-1009.
1.3.1 Inspection of actual installation and documented on BBMU-1009.
1.4.1. Review of drawings BB09-M01000 to assure that redundant altitude switches are present at the TDs console and Operators console.
1.4.2 Inspection of control panels, TD's pane, and documented on BBMU-1009.
1.5.1 Pre-test checklist is used to verify proper operation of the manlock control software and hardware and documented on STB-F-1196.

Hazard Title: **INADVERTENT CHAMBER DEPRESSURIZATION**			**HAWS No.** 3
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/C/2	I/E/4

1.6.1 See Manlock control panel picture figure 3 and drawing BB09-M01000.
1.6.2 Inspection of control panels, TD's pane, and documented on BBMU-1009.
1.7.1 Inspection of control panels, TD's pane, and documented on BBMU-1009.
1.8.1 Verify that closeout procedure has steps to verify personnel are not trapped in the chamber prior to pump down.
2.1.1 Review of personnel qualifications and training records.
2.2.1 See Manlock control panel picture figure 3 and drawing BB09-M01000.
2.2.2 Inspection of control panels, TD's pane, and documented on BBMU-1009.
2.3.1 Inspection of control panels, TD's pane, and documented on BBMU-1009.
2.4.1 Inspection of control panels, TD's pane, and documented on BBMU-1009.
2.5.1 Review of personnel qualifications and training records.
2.6.1 Review of personnel qualifications and training records.
2.7.1 Review of drawings BB09-M01000 to assure that redundant altitude switches are present at the TDs console and Operators console.
2.7.2 Inspection of control panels, TD's pane, and documented on BBMU-1009.
2.8.1 Verify that closeout procedure has steps to verify personnel are not trapped in the chamber prior to pump down.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.4 Hazard Analysis Worksheet – Oxygen Deficient Atmosphere

Hazard Title: OXYGEN DEFICIENT ATMOSPHERE			HAWS No. 4
System: Chamber B	**Subsystem:**	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:
Personnel working in the Manlocks or main chamber when the oxygen concentration goes below 19.5% by volume causing loss of consciousness, potential contact with hard surfaces, and/or death.

Hazard Causes:
1. LN_2 flowing into the chamber or manlock and it is not known to personnel working in the chamber.
2. GN_2 flowing into the chamber or manlock and it is not known to personnel working in the chamber.
3. Ventilation fan not working when personnel working in the chamber.

Hazard Controls:

1.1 Personnel will test atmosphere prior to entering to verify that oxygen content is above 19.5% by volume per STB-063.
1.2 Personnel will wear personal oxygen meters or work with area monitors while working in the chamber and behind the cold walls per STB-063 and any confined space permit and procedure.
1.3 Work behind the cold walls is considered a confined space and requires a confined space permit for entry.
1.4 The ventilation fan is required to be operational at all times when personnel are in the chamber.
1.5 LN2 will not be used during the test.
1.6 Air for the subject inside the suit is provided by a small fan located outside the chamber. Backup compressed air will be supplied off of K-bottles.
2.1 Personnel will test atmosphere prior to entering to verify that oxygen content is above 19.5% by volume per STB-063.
2.2 Personnel will wear personal oxygen meters or work with area monitors while working in the chamber and behind the cold walls per STB-063 and any confined space permit and procedure.
2.3 Work behind the cold walls is considered a confined space and requires a confined space permit for entry.
2.4 The ventilation fan is required to be operational at all times when personnel are in the chamber.
2.5 Air for the subject inside the suit is provided by a small fan located outside the chamber. Backup compressed air will be supplied off of K-bottles.
3.1 If the ventilation fan fails, then both a visual and audible alarms are sounded at the manlock and at the TD console.
3.2 The Toshiba also monitors the fan operations.

Hazard Control Verifications:

1.1.1 Review of TPS's and 611's to ensure that a cautionary note to test the atmosphere prior to entry is present.
1.1.2 Review of TPS's and 611's to ensure that a cautionary note to turn on the exhaust fan prior to entry is present.
1.2.1 Inspections of O2 monitor to ensure that it is in good working order.
1.3.1 Review of TP's and 611's to assure that a note is present about any work behind the cold wall is done with a confined space procedure and permit.
1.4.1 Review of TPS's and 611's to ensure that a cautionary note to turn on the exhaust fan prior to entry is present.
1.4.2 Review and approval of the confined space work procedures.
1.4.3 Review and approval of the confined space work permit.
1.5.1 Review of applicable drawings in DTP to verify no LN2 systems are listed.
1.5.2 Look at the Toshiba to assure that the fan is running.
1.5.3 Listen for the exhaust fan.
1.6.1 Inspect the breathing air setup to assure that it meets the OSHA requirements.
2.1.1 Review of TPS's and 611's to ensure that a cautionary note to test the atmosphere prior to entry is present.

Hazard Title: **OXYGEN DEFICIENT ATMOSPHERE**			**HAWS No.** 4
System: Chamber B	**Subsystem:**	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

2.1.2 Review of TPS's and 611's to ensure that a cautionary note to turn on the exhaust fan prior to entry is present.
2.2.1 Inspections of O2 monitor to ensure that it is in good working order.
2.3.1 Review of TP's and 611's to assure that a note is present about any work behind the cold wall is done with a confined space procedure and permit.
2.4.1 Review of TPS's and 611's to ensure that a cautionary note to turn on the exhaust fan prior to entry is present.
2.4.2 Review and approval of the confined space work procedures.
2.5.1 Review of applicable drawings in DTP to verify no GN2 systems are listed.
2.5.2 Look at the Toshiba to assure that the fan is running.
2.5.3 Listen for the ventilation fan.
3.1.1 Listen for the ventilation fan.
3.2.1 Look at the Toshiba to ensure that the fan is running.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.5 Hazard Analysis Worksheet – Personnel Falling

Hazard Title: PERSONNEL FALLING			**HAWS No.** 5
System: Chamber B	**Subsystem:**	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/D/3

Hazard Description & Consequence:
Personnel are exposed to slick or uneven surfaces. Personnel are exposed to openings in floor or walkways. Exposure causes personnel to be injured.

Hazard Causes:
1. Liquids are spilled on the walking surfaces causing personnel to slip.
2. Joints on adjoining surfaces are greater than ¼ inch causing personnel to trip.
3. There are openings in the walkways large enough for personnel to partially or totally fall into the opening.
4. Platforms are elevated greater than four (4) feet about the adjacent surfaces causing personnel to fall to a lower level.
5. Suited Subject falls during operational testing.
6. Suited subject falls due to obstruction in work area.
7. Suited subject falls due to entanglement in consumable umbilicals.

Hazard Controls:
1.1 Care is taken to prevent liquid spills. Spills are cleaned up immediately upon occurrence.
2.1 Floors are periodically inspected and if found to be uneven, then they are modified to smooth out the surfaces as much as possible.
3.1 Large openings are modified to prevent personnel from falling into the holes.
4.1 All platforms are with fall protection systems installed or provisions for fall protection attach points.
5.1 A rail will be placed alongside the subject for assistance.
5.2 Subjects are fit checked in Building 34 prior to going to Chamber B.
5.3 A dry run is performed prior to chamber run.
5.4 Chamber surface is a diamond plate to reduce tripping.
6.1 Items that cannot be removed from test area are identified during safety briefing.
7.1 Technicians mind umbilicals throughout dry run.

Hazard Control Verifications:
1.1.1 Review of procedures to assure that a cautionary note is in all procedures regarding the removal of all spills when they happen.
1.1.2 Review spill removal during morning toolbox meetings.
2.1.1 Review of inspection records.
2.1.2 Walking surfaces are inspected prior to each activity around the chamber to assure that floor discontinuities are not present.
3.1.1 Inspect walking surfaces for large openings and modify as required.
4.1.1 Inspect all platforms to assure that fall protection systems are in place and being used.
5.1.1. Inspect for rail in the chamber prior to bringing the suited subject into the chamber.
5.2.1 Review fit check records.
5.3.1 Witness dry run prior to chamber run.
5.4.1 Inspect the floor to assure that floor is diamond plate and not grating.
6.1.1 CTSD-ADV-947, Section II, Part F outlines the test subject safety briefing.
7.1.1 CTSD-ADV-947, Section II, Part G reminds techs to handle the umbilical

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.6 Hazard Analysis Worksheet – Loss of PLC

Hazard Title: LOSS OF PLC				**HAWS No.** 6
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
PLC fails causing loss of control for the Manlock, which in turn causes potential equipment damage, potential injury, and/or potential death to personnel. Erratic PLC operation due to incorrect software programming causes erratic control operations cause damage to equipment, potential injury, and/or death to personnel.

Hazard Causes:
1. PLC hardware or software failure
2. Network failure
3. Excessive electromagnetic interference (EMI) emission from electronic devices in the vicinity
4. Unauthorized software programming
5. PLC software has been programmed incorrectly or incorporating errors causing the chamber or manlock to malfunction.

Hazard Controls:
1.1 Each PLC module has status light to indicate the module health. Pre-test checklist shall verify these status lights
1.2 Pre-test checklist shall perform health static check on PLC such as valve control via joystick, etc.
1.3 Manlock control system is designed to go through the PLC or to bypass the PLC using joystick for depress/repress controls. Manual ER controls are located outside the manlocks
1.4 Multiple instrumentation data displays are available for manlock control operator to view. Operator is always required to operate each manlock control system
1.5 Acceptance test was performed to certify the new manlock control system (hardware and software)
2.1 PLC operation does not depend on the network. Network is only used to verify correct software program prior to test
3.1 Facility electrical buildup is in compliance with STB-F-361, “Electrical Guidelines For Facility Modifications And Test Build-Ups”, and the NEC
3.2 PLC is COTS and cables are shielded
3.3 Cellular phone and radio headset will be evaluated in the acceptance test to verify no EMI problem.
4.1 Software is designed to require password access.
4.2 Laptop computer is required to be connected to the PLC for software programming activity.
4.3 Pre-test checklist verifies correct software program.
4.4 PLC cabinet is secured by a key lock. Keys shall be maintained by only by authorized personnel.
5.1 Software is tested at each step to assure proper operations.
5.2 Software is configuration controlled.

Hazard Control Verifications:
1.1.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level to assure that the PLCs have status lights to indicate the module health.
1.1.2 Inspect the installation to assure that all controls work as designed.
1.2.1 Review pre-test checklist to assure that all functions are covered on the PLC.
1.3.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level to assure that the PLCs operate as desired.
1.3.2 Inspect the installation to assure that all controls work as designed.
1.4.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level to assure that the PLCs have status lights to indicate the module health.
1.4.2 Inspect the system to assure that controls and displays are located on at least two different panels.
1.5.1 Review test procedures to assure that PLCs are completely checked out during inspections and test.
2.1.1 Review of drawings to assure that PLCs are not network dependent and are in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.
2.1.2 Inspect the system installation and functional checkout to assure that network is not required for PLC

Hazard Title: LOSS OF PLC			**HAWS No.** 6
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

functioning.

3.1.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.
3.1.2 Inspection of the system after installation to assure that system works as designed.
3.2.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.
3.2.2 Inspection of the manlocks.
3.2.3 Review of the Allen-Bradley PLC cut sheet.
3.3.1 Review procedure to assure the warnings are provided concerning cell phone and radio traffic other than headsets during operations.
4.1.1 Review of software protocol and hardware to assure that passwords are required for access.
4.2.1 Assure that laptop for PLC software programming it controlled hardware and not readily accessible.
4.3.1 Review of pre-test checklist to verify that correct software program is loaded and running.
4.4.1 Assure the PLC cabinets are key controlled and that key is maintained only by authorized personnel.
5.1.1 Review of software to assure that programming has been tested using simulated inputs and outputs as need to assure proper operations.
5.1.2 Review of the DTP to assure that software has been tested and accepted prior to the test run.
5.2.1 Review to assure that software has been configuration controlled.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.7 Hazard Analysis Worksheet – Loss of Depress/Repress Control

Hazard Title: LOSS OF DEPRESS/REPRESS CONTROL			**HAWS No.** 7
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:
CM suffers vacuum related hazards such as ear damage on sudden repress (sudden large leak or ER), bends potential on sudden unexpected depress, or exposure to negative pressure.

Hazard Causes:
1. Loss of repress capability.
2. Sudden repress or inadvertent activation of the ER.
3. Depress of Manlocks too quickly, to too high an altitude (B2), or equalization valve/check valves fail open.

Hazard Controls:
1.1 Redundancies are provided for the nominal and ER system and controls.
1.2 Chamber integrity verified before use.
1.3 Test rules address procedures for repress and depress anomalies.
1.4 Medical personnel are on standby at the chamber.
2.1 Toshiba computer operators receive adequate training.
2.2 ER switches are clearly marked and covered to prevent casual contact.
2.3 Medical personnel are on standby at the chamber.
3.1 Chamber integrity is verified prior to use.
3.2 Due to suit/chamber configuration, test subject will remain at site pressure regardless of chamber pressure.
3.3 Test rules address procedures for repress and depress anomalies.
3.4 Medical personnel are on standby at the chamber.

Hazard Control Verifications:
1.1.1 Review of drawings to assure that redundancies are built in.
1.1.2 Inspection of the facility to assure that redundancies are present in the actual system.
1.2.1 Review of procedures/checklist to assure that chamber integrity is verified.
1.2.2 Review of TPS/DTP.
1.3.1 Review of test rules to assure that procedures for repress and depress anomalies are called out.
1.4.1 Review of medical personnel requirements.
2.1.1 Review of operator training records.
2.2.1 Inspection of actual control panels.
2.3.1 Review of medical personnel requirements.
3.1.1 Review of procedures/checklist to assure that chamber integrity is verified.
3.1.2 Review of TPS/DTP.
3.2.1 Review of procedures/checklist to assure that chamber integrity is verified.
3.2.2 Review of TPS/DTP.
3.3.1 Review of test rules to assure that procedures for repress and depress anomalies are called out.
3.4.1 Review of medical personnel requirements.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.8 Hazard Analysis Worksheet – Loss of Electrical Power

Hazard Title: LOSS OF ELECTRICAL POWER				HAWS No. 8
System:	**Subsystem:**	**Severity/Likelihood/RAC**		
LN_2 System	Electrical	**Before Hazard Controls**	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
Loss of power causes loss of cooling capability, which causes the LN_2 to possible flash to gas. Possible overpressure. Possible loss of test. Possible catastrophic failure of the LN_2 system. Potential for equipment damage. Potential for injury and/or death to personnel.
Total loss of power would result in the following configurations for the Boil-Off Tank System:
All control valves would continue to operate nominally while on UPS.

If eventually total power was lost including UPS:

Supply Control Valve CV-1393 – CLOSED
Supply Control Valve CV-3054 – CLOSED
Bypass Control Valve CV-1397 – OPEN
Chamber B Return Control Valve CV-1321 – CLOSED
Back-Pressure Control Valve CV-1323 – OPEN

Hazard Causes:

1. Loss of power to the building.
2. Loss of power to the center.
3. Loss of UPS System after loss of power to building.

Hazard Controls:

1.1 Loss of power to the building will cause the UPS to kick in and power some systems to allow for the safing of the system and an emergency repress of the chamber. Any personnel in the chamber are brought back to ambient and removed from the chamber. It is not intended to work for extended operations, only to allow the systems to go to a "Safe" Configuration and personnel to be removed from the chamber. It is not intended to work for extended operations, only to allow the systems to go to a "Safe" Configuration.
1.2 Technicians and engineers are trained to respond to facility emergencies.
1.3 Test subjects briefed on emergency response prior to Chamber B test.
1.4 Chamber B performs an Emergency Repress (ER) and Test Subjects are removed from the Chamber B, if loss of power occurs.
2.1 The UPS will kick in to power systems so that safing can occur.
2.2 Technicians and engineers are trained to respond to facility emergencies.
2.3 Test subjects briefed on emergency response prior to test.
2.4 Chamber B performs an Emergency Repress (ER) and Test Subjects are removed from the Chamber B, if loss of power occurs.
3.1 UPS system health is monitored with regular inspections of the batteries.
3.2 Technicians and engineers are trained to respond to facility emergencies.
3.3 Test subjects briefed on emergency response prior to Chamber B test.
3.4 Chamber B performs an Emergency Repress (ER) and Test Subjects are removed from the Chamber B, if loss of power occurs.

Hazard Control Verifications:

1.1.1 Review of data system drawings to assure that the desired systems are powered from the UPS, if loss of power occurs.
1.1.2 Inspection of the UPS system to assure that it is built to the drawings.
1.2.1 Certification letters on file in EC and in B34.
1.3.1 Attend Test subjects briefed on emergency response prior to test.
1.4.1 Review of DTP to assure that loss of power is a test shutdown protocol.
1.4.2 Perform dry runs of the system prior to actual test that include actuation of the ER system.
2.1.1 Review of UPS system drawings to assure that the desired systems are powered from the UPS.

Hazard Title: **LOSS OF ELECTRICAL POWER**			**HAWS No.** 8
System: LN_2 System	**Subsystem:** Electrical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

2.1.2 Inspection of the UPS system to assure that it is built to the drawings.
2.1.3 Testing of the UPS prior to each test to assure that the cross over switch is functioning properly.
2.2.1 Certification letters on file in EC and in B34.
2.3.1 Test subjects briefed on emergency response prior to test.
2.4.1 Review of DTP to assure that loss of power is a test shutdown protocol.
2.4.2 Perform dry runs of the system prior to actual test that include actuation of the ER system.
3.1.1 Review of the control system drawings to assure that all UPS health can be monitored.
3.2.1 Certification letters on file in EC and in B34.
3.3.1 Test subjects briefed on emergency response prior to test.
3.4.1 Review of DTP to assure that loss of power is a test shutdown protocol.
3.4.2 Perform dry runs of the system prior to actual test that include actuation of the ER system.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.9 Hazard Analysis Worksheet – Manlock Control Valve Failure

Hazard Title: MANLOCK CONTROL VALVE FAILURE			**HAWS No.** 9
System: Chamber B	**Subsystem:** Mechanical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:
Unable to operate control valves of manlock control system causing either personnel to be trapped in the manlock.

Hazard Causes:
1. Loss of facility air supply.
2. Control valve failure.

Hazard Controls:
1.1 Backup air supply is available on the air compressors (compressors are not on backup power system).
1.2 System checkout prior to a human test.
1.3 Manual ER controls are located outside the manlocks.
2.1 System checkout prior to a human test.
2.2 Manual ER controls are located outside the manlocks.

Hazard Control Verifications:
1.1.1 Review of pre-test checklist to assure that backup air supply is checked.
1.1.2 Inspection of the facility
1.2.1 Inspection of the facility
1.3.1 Review of checklist to assure that system is inspected and tested as part of the pre-test checklist.
2.1.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.
2.1.2 Inspection of the manlocks.
2.2.1 Review of drawings to assure that electrical design is in accordance with Paragraph 4.6 of STB-F-361 at the PDR & CDR level.
2.2.2 Inspection of the manlocks.

Remarks:
(Note: Facility air supply is not within the scope of the new manlock control project)

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.10 Hazard Analysis Worksheet – Personnel Struck By Manlock Door

Hazard Title: PERSONNEL STRUCK BY MANLOCK DOOR			**HAWS No.** 10
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		III/A/2	III/D/5

Hazard Description & Consequence:
Manlock door strikes personnel or suited subject causing damage to the suit or injury to personnel.

Hazard Causes:
1. Manlock outer doors swing open during repress or ER operations.

Hazard Controls:
1.1 DTP contains caution note to direct all personnel remaining clear of the manlock outer doors during ER operations
1.2 Test rules to rope off area in front of manlock outer doors to prevent personnel from possible injury.

Hazard Control Verifications:
1.1.1 Review of DTP to assure that a warning has been included to warn personnel to stay clear of the door at all times when the chamber is under vacuum.
1.2.1 A step is present in the DTP to rope off the area around the manlock doors.
1.2.2 Assure that a rope is indeed present during test.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.11 Hazard Analysis Worksheet – Contamination

Hazard Title: CONTAMINATION			**HAWS No.** 11
System: Chamber B	**Subsystem:** All	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:
Out-gassing, fire, or toxic substance contamination of chamber materials. Chamber surfaces become contaminated and expose personnel, equipment, and facility to unnecessary contamination causing damage to equipment, facilities, flight hardware, and/or personnel.

Hazard Causes:
1. Improper materials selection causing contamination due to outgassing during pump down.
2. Poor cleanliness procedures during buildup.

Hazard Controls:
1.1 All materials are reviewed for outgassing and possible contamination of chamber components during the design process.
1.2 All materials are reviewed and approved by the Materials Usage Board or the cognizant engineer prior to use in the chamber.
2.1 Chamber is cleaned to the appropriate level during test buildup.
2.2 Chamber cleaning is inspected to assure that it has been cleaned to the appropriate level.

Hazard Control Verifications:
1.1.1 Review of design and facility drawings to assure that selected materials have gone through the appropriate levels of review.
1.1.2 Review of an approved JSC Form 1370 or other materials approval.
2.1.1 Review of cleaning procedures to assure that the appropriate levels of cleanliness have been called out.
2.2.1 Inspection of the chamber to assure that the appropriate level of cleanliness has been achieved.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.12 Hazard Analysis Worksheet – Sharp Edges/Corners & Pinch Points

Hazard Title: **SHARP EDGES/CORNERS & PINCH POINTS**			**HAWS No.** 12
System: Chamber B	**Subsystem:**	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		III/B/3	III/D/5

Hazard Description & Consequence:
Test personnel are struck by sharp edges, corners, snags, or burrs causing lacerations to the part of the body struck.

Hazard Causes:
1. Facility equipment or test articles having protrusions, corners, burrs or sharp edges
2. Striking the Z1 SUIT against sharp edges or corners on the floor or support structure
3. Personnel caught in pinch points.

Hazard Controls:
1.1 All edges are designed to the requirements of NASA/SP-2010-3407. Edges that personnel can come in contact, 6.4 mm (0.25 in.) thick or greater are rounded to a minimum radius of 3.0 mm (0.12 in.). Edges that personnel can come in contact, 3.0 to 6.4 mm (0.12 to 0.25 in.) thick are rounded to a minimum radius of 1.5 mm (0.06 in.). Edges that personnel can come in contact, 0.6 to 3.0 mm (0.02 to 0.12 in.) thick are rounded to a full radius. The edges of thin sheets less than 0.5 mm (0.02 in.) thick are rolled or curled.
1.2 All edges are designed to the requirements of NASA/SP-2010-3407. Exposed corners of materials that exceed 25 mm (1.0 in.) thickness are rounded to 13 mm (0.5 in.) spherical radius. Exposed corners of materials less than 25 mm (1.0 in.) thick are rounded to a minimum radius of 13 mm (0.5 in.).
2.1 Test system is inspected by TD prior to test initiation to verify all sharp edges/corners have been properly addressed. Tape is used on chamber material edges to reduce edges in close proximity to the suited subject.
3.1 Test Personnel are familiarized with equipment configurations and operational parameters. Pinch point inspection is performed and applicable pinching mechanisms marked/labeled with pinch point caution statement.
3.2 Ergonomically designed handles are provided for all lift points.

Hazard Control Verifications:
1.1.1 Review of drawings to assure corners and sharp edge are not present in the design at the PDR & CDR level.
1.1.2 Inspection of the hardware prior to test to assure that sharp edges, corners, burrs, and snags do not exist.
1.2.1 Review of drawings to assure corners and sharp edge are not present in the design at the PDR & CDR level.
1.2.2 Inspection of the hardware prior to test to assure that sharp edges, corners, burrs, and snags do not exist.
2.1.1 Review DTP to assure that a sharp edge inspection of the hardware is called out prior to test to assure that sharp edges, corners, burrs, and snags do not exist.
2.1.2 Review DTP to assure that a sharp edge inspection of the hardware is called out prior to test to assure that sharp edges, corners, burrs, and snags do not exist.
3.1.1 Review of drawings to assure pinch points are not present in the design at the PDR & CDR level.
3.2.1 Review of drawings to assure ergonomically designed handles are used at the PDR & CDR level.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.13 Hazard Analysis Worksheet – Structural Failure

Hazard Title: STRUCTURAL FAILURE			**HAWS No.** 13
System: Chamber B	**Subsystem:** Mechanical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

Hazard Description & Consequence:
Structural failure of handles, hinges, floor panels, subfloor panels, and/or support structure causing the doors to fall on the personnel or suited subject. Inadequate design or failure of the SIP while pressurized to 8.3 psid and attached to the suitport with personnel (suit subject or support personnel) in the vicinity. Vacuum system fails due to structural failure causing damage to equipment, damage to the facility, or injury and/or death to personnel

Hazard Causes:
1. Improper design of the chamber rails, doors, floor, etc.
2. Improper materials.
3. Use of non-conforming fasteners.
4. Structural failure of the Chamber.
5. Inferior welds on the Chamber.
6. Suitport structural failure.
7. Improper design suitport interface plate (SIP).

Hazard Controls:
1.1 Doors are designed to withstand a 600-lbf load with a safety factor of 3.0 to ultimate, with all positive margins. See stress analysis ESCG-4450-05-STAN-DOC-0115.
1.2 A proof load test was performed Wednesday, October 19, 2005 on the Manlocks.
2.1 All materials are reviewed by the MUCB prior to being allowed into the chamber for operations.
3.1 All chamber fasteners are certified tested at the RITF.
4.1 Chamber has been reviewed by the PSMO as a pressure vessel and found to be adequately designed.
5.1 All welds are IAW AWS standards at the time of construction.
6.1 The Suitport is designed to withstand pressure and crewmember loads with the ultimate factor of safety of 2.0 and yield factor of safety 1.65. See analysis ESCG-4450-12-STAN_DOC-0056.
6.2 There is an approved OCCP for the pneumatic flipper assembly. See OCCP ES4-12-084.
6.3 The suit is tested to 1.5 MAWP during checkout in the chamber.
7.1 FEA performed which verified that suit/SIP had a minimum FOS of 5.9 relative to yield when a 17.6 psi differential pressure was applied across the suit/SIP while attached to the suitport.

Hazard Control Verifications:
1.1.1 Review of drawings to assure that the appropriate loads have been given as the design loads.
1.1.2 Review of stress analysis ESCG-4450-05-STAN-DOC-0115 to assure that all factors of safety are appropriate.
1.2.1 Review of proof test data.
2.1.1 Review of drawings to assure that materials are in accordance with STB-E-001, STB-F-366, STB-E- 083, & JSC 09604 at the PDR & CDR level.
2.1.2 Inspection of all systems mechanical systems, parts, and components to assure that they are built in accordance with the drawings.
2.1.3 Review of the proof load test performed on 10/19/2005.
3.1.1. Review of fasteners to assure that they meet requirements.
4.1.1 Review of chamber stress calculations.
5.1.1 Structural welds are inspected for voids and cracks.
6.1.1 Review of stress analysis ESCG-4450-12-STAN-DOC-0056.
6.2.1 Review of OCCP.
6.3.1 Review of the DTP.
7.1.1 Review of Z-1 Rear Entry Closure and SPIP Finite Element Analysis

Remarks:

Suit pressurization hazards are covered by HAWS A24

Hazard Title: **STRUCTURAL FAILURE**				**HAWS No.** 13
System: Chamber B	**Subsystem:** Mechanical	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.14 Hazard Analysis Worksheet – Impact/Collision

Hazard Title: **IMPACT/COLLISION**			**HAWS No.** 14
System: Chamber B	**Subsystem:** Mechanical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		II/B/2	II/D/4

Hazard Description & Consequence:
System collides with crewmember, other personnel, or surrounding structure in the manlock causing damage to equipment, injury, to personnel.

Hazard Causes:
1. Misalignments during suit port redock.
2. Suit/suit port interference with surrounding structures.
3. Suit hatch opened with excess suit pressure.

Hazard Controls:
1.1 Alignment guides provided to assist test subject in aligning suit port for redock.
1.2 Test subject rehearses docking operations during dry run.
2.1 Suit port designed to avoid interference with chamber systems/structures.
2.2 Limited planned mobility of test subject while undocked.
3.1 Reduce flow to suit.
3.2 Remove umbilical (air outlet) connector prior to opening the hatch.

Hazard Control Verifications:
1.1.1 Inspection of chamber for alignment guides.
1.2.1 Dry run conducted prior to test.
2.1.1 Review of drawings to ensure that suit port has been designed accordingly.
2.1.2 Inspection of the system prior to test.
2.2.1 Review of DTP sequences.
2.2.2 Dry run conducted to instruct test subject on undocked suit operations
3.1.1 A step in DTP CTSD-ADV-1003.
3.2.1 A step in DTP CTSD-ADV-1003.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.15 Hazard Analysis Worksheet – Contact with or Inhalation of Toxic Substance

Hazard Title: **CONTACT WITH OR INHALATION OF TOXIC SUBSTANCE**			**HAWS No.** 15
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC** **Before Hazard Controls** II/A/1	**After Hazard Controls** II/E/5

Hazard Description & Consequence:
Hardware damage and personnel injury.

Hazard Causes:
1. Use of unapproved materials or lubricants for maintenance.
2. Subject introduces contaminants on clothing.
3. Materials placed in closed volume of suit offgas toxic substance.
4. Toxic material, CO, or CO_2 is introduced via the breathing air system.

Hazard Controls:
1.1 Maintenance manual documents approved procedures and materials for suit maintenance.
2.1 Test subjects provided with protective booties to wear over socks prior to donning suit.
3.1 Items in suit have been approved for use by similarity to EMU flight hardware.
4.1 There is a multigas analyzer in close proximity to the breathing air intake.
4.2 There is a temperature sensor on the blower to detect overtemperature conditions in the breathing air system.
4.3 There is a backup breathing air bottle rack that is connected to the breathing air system for emergencies.

Hazard Control Verifications:
1.1.1 CTSD-ADV-1003 provides for materials review.
2.1.1 CTSD-ADV-1003 provides for materials review.
3.1.1 Vendor supplied materials usage memo.
3.1.2 An approved MUL #11-005.
4.1.1 Review of drawing BB25-M55001.
4.1.2 Inspection of breathing air system.
4.2.1 Review of drawing BB25-M55001.
4.2.2 Inspection of breathing air system.
4.3.1 Review of drawing BB25-M55001.
4.3.2 Inspection of breathing air system.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.16 Hazard Analysis Worksheet – Accidental Flipper Mechanism Release

Hazard Title: ACCIDENTAL FLIPPER MECHANISM RELEASE				**HAWS No.** 16
System: Chamber B	**Subsystem:** Suitport	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
Catastrophic injury due to accidental pressurization of pneumatic flippers while at 8.3 psi delta pressure with vestibule door open.

Hazard Causes:
1. Test personnel accidentally command open Flipper clamps.
2. Software system malfunction causes solenoid valve to open causing Flipper clamps to inadvertently open.
3. Test Subject manually actuates flipper mechanism

Hazard Controls:

1.1 Review and approval of CTSD-ADV-1003. The PFS operations requires closing the flippers and assuring that the Z-1 suit is secure. Then we verify the suitport vestibule door is open. The manlock inner and outer door for each manlock is verified open. The pressure regulator for the inflatable seal is backed off completely and one of the hand valves is closed. Then inflatable seal solenoid valves are closed. Next the flipper air panel hand valves are closed and the PFS pressure regulator is backed off. Next the solenoid valves for the PFS are closed. The equalization valves for the main chamber to manlock B2, Vestibule to manlock B2 and Vestibule to Main chamber are opened. The vestibule to manlock B2 valve is closed. The inflatable seal vent valve is opened. The PFS vent valve is opened. Breathing air blower is turned off. The pressure regulator is backed off. Breathing air valves are closed. Breathing air inlet and outlet valves are closed. MUCU is turned off. Cooling water inlet and outlet are closed. The main chamber, vestibule, inflatable seal, PFS, and manlock B2 are pressurized to 14.7 psia. During donning the following steps are performed. The utility lines are connected to the suit hatch. Verification of the garments being present is performed. Subject climbs into the suit. The LCG is connected. The cooling water is turned on. The MUCU is turned on. Cooling water is verified. Complete suit donning. Connection of shoulder straps occurs. The hatch is closed. The Comm check is performed. The umbilical is connected. The PLSS mockup is installed. Donning and adjustments of the comfort gloves and suit gloves is performed. Adjustments are made. The helmet and Ortman wire are installed. The suit is pressurized. The boots are removed from the foot restraint. The PFS vent valve is closed the PFS regulator is backed off. The facility air supply is opened to the PFS. The PFS supply valve is opened. Using the PFS regulator, slowly increase PFS supply pressure. Verify that the PHS has fully opened. The suit is undocked from the suit port. The PFS supply valve is closed and the vent valve is opened. The test subject adjusts the boots. The PFS vent valve is closed. The PFS regulator is backed off. The PFS air panel is opened. The PFS supply valves is opened. The pressure on the PFS regulator is used to increase pressure. verify that the flippers have actually opened. The suit is again undocked from the suitport. The supply valve is closed. The vent valve is opened. The subject performs the required task. The test subject inspects the suitport and turns and backs up to the suitport. Loosens the suit boots. Aligns the PLSS mockup with the suitport. Repositions the foot restrain. Close the PFS vent valve. Open the PFS supply valve. Task for doffing are performed in the reverse order.

2.1 Software is tested and configuration controlled prior to the commencement of the test. The PFS operations requires closing the flippers and assuring that the Z-1 suit is secure. Then we verify the suitport vestibule door is open. The manlock inner and outer door for each manlock is verified open. The pressure regulator for the inflatable seal is backed off completely and one of the hand valves is closed. Then inflatable seal solenoid valves are closed. Next the flipper air panel hand valves are closed and the PFS pressure regulator is backed off. Next the solenoid valves for the PFS are closed. The equalization valves for the main chamber to manlock B2, Vestibule to manlock B2 and Vestibule to Main chamber are opened. The vestibule to manlock B2 valve is closed. The inflatable seal vent valve is opened. The PFS vent valve is opened. Breathing air blower is turned off. The pressure regulator is backed off. Breathing air valves are closed. Breathing air inlet and outlet valves are closed. MUCU is turned off. Cooling water inlet and outlet are

Hazard Title: ACCIDENTAL FLIPPER MECHANISM RELEASE			**HAWS No.** 16
System: Chamber B	**Subsystem:** Suitport	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/E/4

closed. The main chamber, vestibule, inflatable seal, PFS, and manlock B2 are pressurized to 14.7 psia. During donning the following steps are performed. The utility lines are connected to the suit hatch. Verification of the garments being present is performed. Subject climbs into the suit. The LCG is connected. The cooling water is turned on. The MUCU is turned on. Cooling water is verified. Complete suit donning. Connection of shoulder straps occurs. The hatch is closed. The Comm check is performed. The umbilical is connected. The PLSS mockup is installed. Donning and adjustments of the comfort gloves and suit gloves is performed. Adjustments are made. The helmet and Ortman wire are installed. The suit is pressurized. The boots are removed from the foot restraint. The PFS vent valve is closed the PFS regulator is backed off. The facility air supply is opened to the PFS. The PFS supply valve is opened. Using the PFS regulator, slowly increase PFS supply pressure. verify that the PHS has fully opened. The suit is undocked from the suit port. The PFS supply valve is closed and the vent valve is opened. The test subject adjusts the boots. The PFS vent valve is closed. The PFS regulator is backed off. The PFS air panel is opened. The PFS supply valves is opened. The pressure on the PFS regulator is used to increase pressure. verify that the flippers have actually opened. The suit is again undocked from the suitport. The supply valve is closed. The vent valve is opened. The subject performs the required task. The test subject inspects the suitport and turns and backs up to the suitport. Loosens the suit boots. Aligns the PLSS mockup with the suitport. Repositions the foot restrain. Close the PFS vent valve. Open the PFS supply valve. Task for doffing are performed in the reverse order.

3.1 There is a pin that secures the release when vestibule door is open
3.2 Test Subject training

Hazard Control Verifications:

1.1.1 Review CTSD-ADV-1003 for donning/doffing.
2.1.1 See drawing BB25-M55005.
2.1.2 Review CTSD-ADV-1003 for donning/doffing.
3.1.1 Inspection of PFS/SIP.
3.2.1 Training records are in EC/building 7, and Building 34.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.17 Hazard Analysis Worksheet – Ignition Source in Test Area Results in Facility Fire and Personnel Injury or Equipment Damage

Hazard Title: **IGNITION SOURCE IN TEST AREA RESULTS IN FACILITY FIRE AND PERSONNEL INJURY OR EQUIPMENT DAMAGE**				**HAWS No.** 17
System: Chamber B	**Subsystem:** Suit Port Test	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
Ignition source in test area results in facility fire and personnel injury or equipment damage

Hazard Causes:
1. Uncontrolled ignition source

Hazard Controls:
1.1 This is a "planned" leak detection activity with a COTS smoke pen.
1.2 The controlled open flame should only be present for approximately 10 – 15 seconds during the ignition cycles of the smoke pen.
1.3 Only trained personnel are authorized to interface with test system.
1.4 No concentrated oxygen required or utilized during the leak detection activity. The test director confirms there are no concentrated oxidizers or fuel sources in the immediate area prior to igniting smoke pen. Smoke pen confirmed to be extinguished after use – per test team briefing.

Hazard Control Verifications:
1.1.1 Review of CTSD-ADV-1003
1.2.1 Review of manufacturer's operating instructions for smoke pen.
1.3.1 Test team briefing per CTSD-ADV-1003.
1.4.1 Review of CTSD-ADV-1003.

Remarks:

The MSDS for the smoke pen has been reviewed and available for test personnel. The active component of the smoke pen is a cotton wick soaked in 2 – 10% stearic acid. Safety review concludes that no adverse health issues results from normal short-duration use of the smoke pen. However, it is recommended that the user avoid breathing or exposing eyes to concentrated streams of smoke. Test rules of detailed test procedures define actions for physical symptoms resulting from smoke pen use. (reference MSDS action for fire)

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.18 Hazard Analysis Worksheet – Loss of Breathing Air Supply to the Test Subject

Hazard Title: **LOSS OF BREATHING AIR SUPPLY TO THE SUBJECT**			**HAWS No.** 18
System: Chamber B	**Subsystem:** Mechanical, Z – 1 Suit	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/D/3

Hazard Description & Consequence:
Loss of breathing air supply to the test subject causes injury and/or death to personnel. (Hypercapnia or Test subject suffocation.

Hazard Causes:
1. Reduction of air flow due to failure of breathing air supply system
2. Reduction of air flow due to blockage in air inlet and outlet line
3. Reduction of air flow due to operator error
4. Contaminated breathing source
5. Insufficient CO2 washout in the oral-nasal area.

Hazard Controls:
1.1 Airflow is verified during crewmember donning monitored throughout test at the air source.
1.2 Inlet and outlet air valves to the suit are tie-wrapped open
2.1 Test subject informed to notify suit engineer if they hear a change in airflow.
3.1 Only certified technicians operate air systems.
4.1 Air supplies are sampled to verify constituent gases and cleanliness.
4.2 Air supply system uses a filter on the inlet to the blower. K-bottle paperwork/sampling verified prior to test. A monitor is installed to check for the presence of CO to prevent the suited subject breathing CO.
5.1 A minimum of 5 ACFM airflow required.
5.2 Test is terminated if suit airflow drops below 5 ACFM for more than 5 minutes, or below 4 ACFM for any period.

Hazard Control Verifications:
1.1.1 Review of procedures.
1.1.2 Review of CTSD-ADV-1003, verifies breathing airflow is initiated
1.1.3 CTSD-ADV-1003, defines test termination criteria specific to airflow rates.
1.2.1 Inspection of the system prior to test.
2.1.1 CTSD-ADV-1003, verifies test subject safety briefing.
3.1.1 Technician training certification letters on file in EC and B34.
4.1.1 STB-F-412 followed for sampling.
4.2.1 Inspection of breathing air system before/during/after the test.
5.1.1 Adequate CO2 washout verified through Z-1 suit CO2 washout testing.
5.2.1 CTSD-ADV-1003, defines test termination criteria.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.19 Hazard Analysis Worksheet – Pressure System Rupture When Pressurizing the Z – 1 Suit

Hazard Title: PRESSURE SYSTEM RUPTURE WHEN PRESSURIZING THE Z – 1 SUIT			**HAWS No.** 19
System: Chamber B	**Subsystem:** Mechanical, Z – 1 Suit	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/A/1	I/D/3

Hazard Description & Consequence:
Pressure system rupture when pressurizing Z-1 SUIT causing damage to equipment, injury and/or death to personnel.

Hazard Causes:
1. GSE pressure system rupture.
2. Breathing Air Hose breaks during pressurization.
3. Inadvertent QD disconnect.

Hazard Controls:
1.1 GSE test support integrated system is Class 1 pressure certified. CTSD-ADV-908, Operating Procedures for the Low Pressure Outlet 6 K-bottle Manifold, will be used for pressurizing the Z1 SUIT during the dry runs. Pressure gage on the K-bottle manifold will be used to monitor the pressure.
2.1 All breathing air hoses have been tested and have a MAWP of 14 psig.
3.1 QDs are Apollo QDs and have a lock-lock feature to prevent inadvertent disconnect.

Hazard Control Verifications:
1.1.1 Review of hose paperwork.
1.1.2 Inspection of the system prior to test.
2.1.1 Inspection of the system prior to use.
3.1.1 Inspection of the system prior to use.

Remarks:

Suit pressure hazards are discussed in HAWS A24

HAW Approval (Use for manned, oxygen, or hazardous testing.)		**Disposition**
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.20 Hazard Analysis Worksheet –Electrical Shock in the Z – 1 Suit

Hazard Title: ELECTRICAL SHOCK IN THE Z – 1 SUIT				**HAWS No.** 20
System: Chamber B	**Subsystem:** Electrical	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		III/A/2	III/D/5	

Hazard Description & Consequence:
Test subject injury.

Hazard Causes:

1. Short in external cooling system.
2. Exposed communications system wiring in the suit.

Hazard Controls:

1.1 System plugged into GFCI outlet or power cord.
2.1 Wires are visually inspected prior to each test.
2.2 Voltages are below the threshold for electrical shock (30V), per NASA/SP-2010-3407.
2.3 120 Vac supplies are voltage/current limiting units and are plugged into UL rated GFCIs.

Hazard Control Verifications:

1.1.1 The suit procedure mandates use of GFCI connection.
2.1.1 ASL Form 001 completed prior to each test verifies functional checkout complete, including inspection of wires.
2.2.1 Review design.
2.3.1 Inspection of setup prior to test.

Remarks:

The electrical shock hazard is covered by CTSD-ADV-819A, Hazard #1.

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.21 Hazard Analysis Worksheet – Umbilical Retractor Failure

Hazard Title: **UMBILICAL RETRACTOR FAILURE**			**HAWS No.** 21
System: Chamber B	**Subsystem:** Mechanical, Z – 1 Suit	**Severity/Likelihood/RAC** **Before Hazard Controls** II/A/1	**After Hazard Controls** II/D/4

Hazard Description & Consequence:
Umbilical retractor pulls the subject backwards resulting in the subject impacting the surrounding structure or tripping and causing damage to the equipment and injury to personnel. Umbilical retractor cable strikes personnel upon cable retract or cable breaks in the extended position causing cable to whip and damage equipment and injury personnel. Umbilical retractor strikes personnel causing injury. Umbilical fails to retract causing trip hazard, which cause injury to personnel.

Hazard Causes:
1. Umbilical has too much tension.
2. Too much tension on the cable.
3. Umbilical retractor cable comes off system during cable retracting.
4. Umbilical retractor cable breaks.

Hazard Controls:
1.1 Umbilical retractor is designed with maximum tension of 5/15 lbs. Tension is evaluated during dry run prior to each test.
2.1 Umbilical retractor is designed with maximum tension of 5/15 lbs.
3.1 Procedure to install umbilical retractor cable prior to system operations is used.
4.1 Umbilical retractor is designed with a maximum tension of 5/15 lbs.

Hazard Control Verifications:
1.1.1 Inspection of the system prior to operation
2.1.1 Review of procedures to assure that the proper operation is used
2.1.2 Inspection of system prior to operation
3.1.1 Review of procedures
3.1.2 Inspection of system post installation
4.1.1 Review of drawings to assure that the umbilical retractor is designed with a minimum tension of 5/15 lb_f.
4.1.2 Inspection of the system

Remarks:

There are two retractor reels. One has a maximum of 5 lb_f pull and the other has a maximum of 15 lb_f pull.

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.22 Hazard Analysis Worksheet – Loss of Cooling Supply to the Test Subject

Hazard Title: LOSS OF COOLING SUPPLY TO THE TEST SUBJECT				**HAWS No.** 22
System: Chamber B	**Subsystem:** Mechanical, Z – 1 Suit	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		III/A/2	III/D/5	

Hazard Description & Consequence:
Loss of cooling supply to test subject causing heat stress injury to suited subject.

Hazard Causes:
1. Cooling system failure.
2. Inadequate cooling

Hazard Controls:
1.1 Cooling system checked out prior to test. Test Director and cognizant suit technician will maintain communication with test subject at all times. Rescue technician is available in the area.
2.1 Cooling system uses an ice chest type cooler.

Hazard Control Verifications:
1.1.1 Inspection of suit setup by TD and Suit Techs prior to each run.
1.1.2 Review of test procedures.
2.1.1 Inspection of the cooling system prior to and during the test.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.23 Hazard Analysis Worksheet – Emergency Rescue Impeded

Hazard Title: EMERGENCY RESCUE IMPEDED			**HAWS No.** 23
System: Chamber B	**Subsystem:** Mechanical	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		I/B/1	I/D/3

Hazard Description & Consequence:
Emergency rescue impede by block pathway causing injury and/or death to personnel, damage to equipment, and injury and/or death to rescue personnel.

Hazard Causes:
1. Physical interference with rescue technicians.
2. Unable to move system out of chamber.

Hazard Controls:
1.1 System is configured to allow space for rescue technician operations.
1.2 Rescue drills performed for rescue scenarios.
2.1 System is configured to allow space for rescue technician operations.

Hazard Control Verifications:
1.1.1 Review of drawings to assure that there are not impediments to travel designed into the system.
1.1.2 Inspection of the facility to assure adequate room for rescue operations.
1.2.1 Observe rescue drill.
2.1.1 Inspection of the facility to assure adequate room for rescue operations.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.24 Hazard Analysis Worksheet – Rapid Suit Depressurization

Hazard Title: RAPID SUIT DEPRESSURIZATION				**HAWS No.** 24
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		I/B/1	I/E/4	

Hazard Description & Consequence:
Injury or death caused by rapid suit depressurization. This includes ear or sinus blockage, arterial gas embolism, and hardware damage during the dry run. It also includes exposure of the test subject to reduced atmospheric pressure (as low as 6.4 psia) during the altitude run.

Hazard Causes:
1. Structural failure caused by defective hardware (seal, seam, etc.) or improper assembly of hardware
2. Structural failure due to overpressurization.
3. Test Stand Operator error.
4. Lock-locks not fully engaged at disconnect leading to hardware becoming inadvertently disconnected from suit.
5. Umbilical ruptures or becomes disengaged, leading to large leak.
6. Accidental hatch release
7. Accidental helmet release
8. Accidental boot release
9. Accidental glove release

Hazard Controls:
1.1 Prior to each test, suit is taken to structural pressure (1.5 FOS over operating pressure), visually inspected, and tested for leakage.
1.2 Maintenance log is reviewed for open items, which are constraints to test prior to each test.
2.1 Calibration of all in-line relief valves prior to test.
2.2 Prior to each test, suit is taken to structural pressure (1.5 FOS over operating pressure), visually inspected, and tested for leakage.
3.1 Technicians operating test stand are certified for that position.
4.1 Engagement of lock-locks verified prior to test.
4.2 Test subject has approx. 5 minutes of useful consciousness at 6.4 psia. Chamber can be repressed in less than 30 seconds or per TD discretion in event of suit depressurization.
5.1 Breathing air umbilicals certified to MAWP of 14 psig.
5.2 Breathing air umbilical connected to suit with Apollo lock-lock connectors.
5.3 Breathing air umbilical connected to fittings with hose clamps.
5.4 Test subject has approx. 5 minutes of useful consciousness at 6.4 psia. Chamber can be repressed in less than 30 seconds or per TD discretion in event of suit depressurization.
6.1 Hatch latch/lock mechanism has two redundant locking tabs.
6.2 Suit technician verifies that suit hatch is locked after closing.
7.1 Suit test engineer verifies that helmet Ortman wire is fully installed prior to test.
7.2 A tolerance study was performed
8.1 Suit test engineer verifies boot Ortman wires fully installed and proper size prior to test.
8.2 A tolerance study was performed.
9.1 Suit test engineer verifies glove properly installed and locks proper size prior to test.

Hazard Control Verifications:
1.1.1 ASL Form 001 reviewed prior to each test to verify checkouts completed.
1.2.1 ASL Form 001 reviewed prior to each test to verify maintenance log reviewed.
2.1.1 ASL Form 001 reviewed prior to each test to verify relief valve cal dates recorded.
3.1.1 Technician certification letters are on file with EC and in the Advanced Suit Lab.
4.1.1 CTSD-ADV-1003, verify all connections are secure.
4.2.1 ER checkouts current.
5.1.1 Inspection of tags on breathing air umbilical.

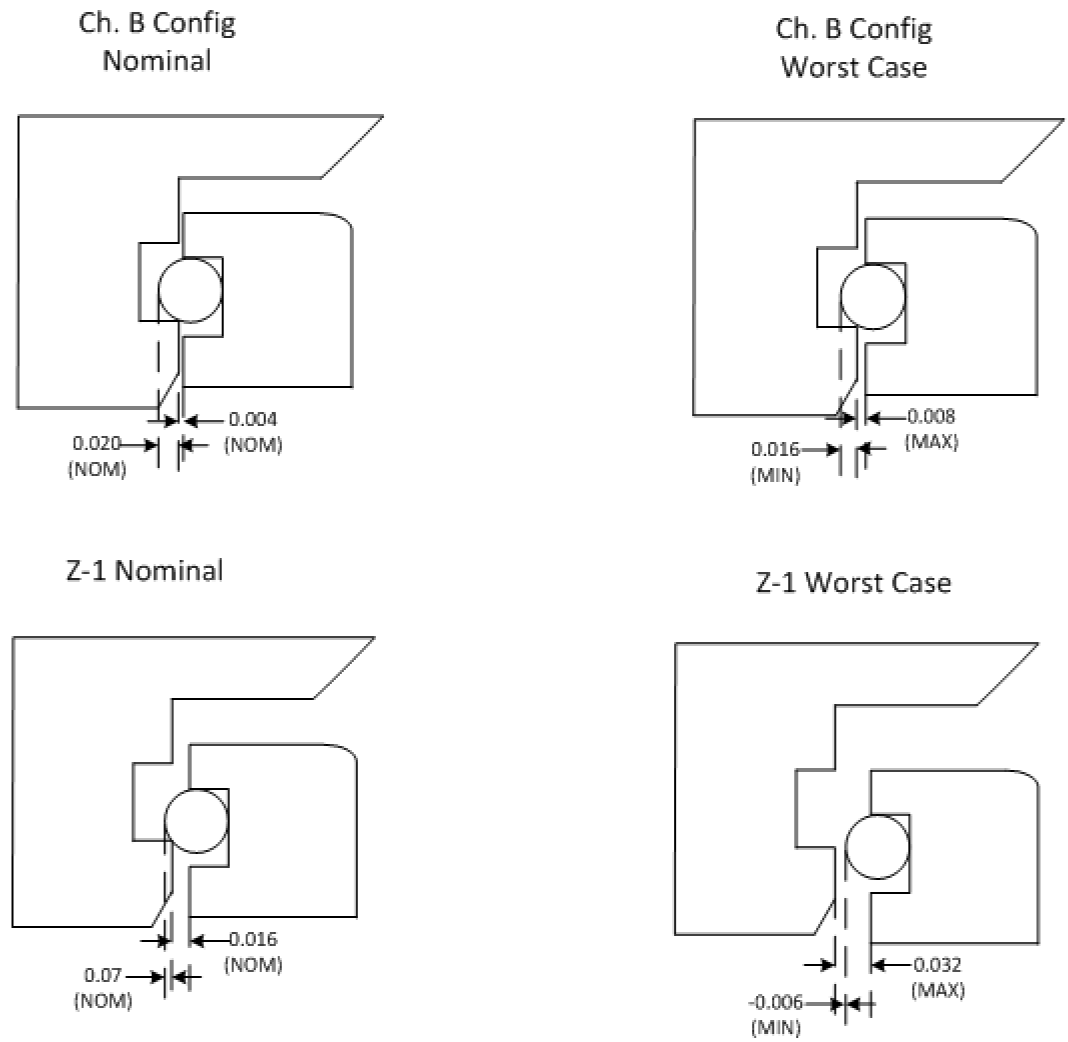
Hazard Title: RAPID SUIT DEPRESSURIZATION				HAWS No. 24
System:	**Subsystem:**	**Severity/Likelihood/RAC**		
Chamber B	Z – 1 Suit	**Before Hazard Controls**	**After Hazard Controls**	
		I/B/1	I/E/4	

5.2.1 Inspection of connectors.
5.3.1 Inspection of umbilical.
5.4.1 ER checkouts current.
6.1.1 Inspection of hatch latch/lock mechanism
6.2.1 Step in DTP, CTSD-ADV-1003
7.1.1 Z-1 chamber closeout checklist
7.2.1 See the Remarks section below.
8.1.1 Z-1 chamber closeout checklist
8.2.1 See the Remarks section below.
9.1.1 Z-1 chamber closeout checklist

Remarks:

During an unmanned pressurized evaluation of a prototype boot jack foot restraint, to be used during pressurized suit donning and doffing, there was partial disconnect of the Z-1 left boot Ortman wire disconnect which resulted in a audible pop and audible suit leakage. Initial evaluation of the failure determined that the disconnect shucked to one side opening a gap in the opposite side of the Ortman wire groove which caused the lip seal to unseat allowing air to pass through. Dimensional/tolerance analysis of the Z-1 boot Ortman wire disconnect groove showed that at maximum dimensions/tolerance the Ortman wire groove width can exceed the maximum width of the Ortman wire used. The same dimensional/tolerance analysis of the Mk III boot Ortman wire disconnect groove showed that at maximum dimensions/tolerance the Ortman wire groove width is within the design tolerances and will not partially disconnect with the test loads.

Measured Dimensions



Additionally, the Mk III disconnects where pulled test to the force equivalent to the man load (240 lbf per axial) and plug load (144 lbf per axial) exerted on the suit when manned pressurized and with a side load that racked the disconnect to one side, leaving the maximum gap along the load edge. Testing showed that the hardware design was sound and acceptable for manned pressurized testing.

Z1 male boot disconnects P/N 26441 S/N 102 and 103 have been replaced by Mark III male boot disconnects P/N

SK752720002 S/N 07 and S/N 09. Suit bearings S/N 102 and 103 have been taken out of service, leaving only S/N 104 and 105 in use. This configuration of the Z1 suit is acceptable for test.

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.25 Hazard Analysis Worksheet – Improper Suit Fit

Hazard Title: IMPROPER SUIT FIT				**HAWS No.** 25
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		III/B/3	III/D/5	

Hazard Description & Consequence:
Subject feels discomfort, reduced mobility, bruising, and/or abrasions.

Hazard Causes:
1. Use of improperly sized equipment.

Hazard Controls:
1.1 Test subjects are required to have a successful fit-check prior to test participation.
1.2 Individual sizing records are used to build up suits prior to test.
1.3 Certified suit engineers trained in sizing philosophy.

Hazard Control Verifications:
1.1.1 Documentation of proper fit check.
1.2.1 Z-1 use log requires date of fit check to be recorded prior to test. ASL Form 001 reviewed prior to each test, which is signed off by a designated verifier who checked proper suit sizing.
1.3.1 Suit Engineer Certifications are on file in EC and B34.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.26 Hazard Analysis Worksheet – Aspiration of Vomit

Hazard Title: **ASPIRATION OF VOMIT**			**HAWS No.** 26
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC** **Before Hazard Controls** I/C/2	**After Hazard Controls** I/E/4

Hazard Description & Consequence:
Test subject is seriously injured or suffocated during test.

Hazard Causes:
1. Subject vomits in suit.

Hazard Controls:
1.1 Test subject is informed of hazards associated with vomit in the suit and instructed on response to nausea.
1.2 Suit team is trained to respond quickly to vomit in suit.

Hazard Control Verifications:
1.1.1 Test subject safety briefing.
1.2.1 Certification letters on file in EC and B34.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.27 Hazard Analysis Worksheet – Muscle Cramps or Exhaustion

Hazard Title: **MUSCLE CRAMPS OR EXHAUSTION**			**HAWS No.** 27
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		III/A/2	III/D/5

Hazard Description & Consequence:
Personnel injury due to muscle cramps.

Hazard Causes:
1. Overexertion by suited subject.
2. Dehydration.

Hazard Controls:
1.1 Subject can stop participation at any time.
1.2 Test personnel monitor test subject for signs of overexertion during all suited activities.
2.1 Subjects are asked if they are properly hydrated prior to test.

Hazard Control Verifications:
1.1.1 Test subject safely briefing.
1.2.1 Certification letters on file in EC and B34.
2.1.1 Test subject safety briefing.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.28 Hazard Analysis Worksheet – Subject Entrapment

Hazard Title: SUBJECT ENTRAPMENT				**HAWS No.** 28
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**		
		Before Hazard Controls	**After Hazard Controls**	
		III/B/3	III/E/6	

Hazard Description & Consequence:
Equipment damage and/or personnel injury.

Hazard Causes:
1. Rear hatch jammed.

Hazard Controls:
1.1 Smooth operation closure verified during pre-test functional checkout.
1.2 Scenario is reviewed during annual emergency event training.

Hazard Control Verifications:
1.1.1 ASL Form 001 reviewed prior to each test for designated verifier (DV) signature. DV checks for nominal operation of all suit disconnects and locking mechanisms.
1.2.1 STE certification letters on file in EC5 and B34.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated

A.29 Hazard Analysis Worksheet – Hyperventilation

Hazard Title: **HYPERVENTILATION**			**HAWS No.** 29
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		III/B/3	III/D/5

Hazard Description & Consequence:
Personnel injury due to hyperventilation.

Hazard Causes:
1. Subject anxiety or overexertion during test.

Hazard Controls:
1.1 Subjects are briefed on suit hazards prior to test and informed they may stop the test at any time.
1.2 Suit engineers trained to recognize signs of anxiety and over exertion and may stop the test at any time.

Hazard Control Verifications:
1.1.1 Test subject safety briefing.
1.2.1 Suit engineers are certified for operations and the letters are on file in EC5 and B34.

Remarks:

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	**X**	Closed/Controlled
		Closed/Eliminated

A.30 Hazard Analysis Worksheet – Loss of Two Way Verbal Communications

Hazard Title: **LOSS OF TWO-WAY VERBAL COMMUNICATIONS**			**HAWS No.** 30
System: Chamber B	**Subsystem:** Z – 1 Suit	**Severity/Likelihood/RAC**	
		Before Hazard Controls	**After Hazard Controls**
		III/B/3	III/D/5

Hazard Description & Consequence:
Personnel injury due to loss of two-way communications.

Hazard Causes:
1. Component failure (wires disconnected, short, loss of power).
2. Improper SPACIS configuration.

Hazard Controls:
1.1 Communication system functions are verified prior to test.
1.2 Condition of wires verified prior to test.
1.3 Subjects are briefed on termination criteria associated with loss of Comm. and alternate comm. Modes in the event of comm. loss.
2.1 Communication system checkout prior to test to verify proper configuration.

Hazard Control Verifications:
1.1.1 ASL Form 001 reviewed prior to each test to verify that comm. check is completed.
1.2.1 ASL Form 001 reviewed prior to each test to verify designated verifier (DV) signature. DV checks that comm. system is secured and properly routed.
1.3.1 Test subject safety briefing.
2.1.1 Engineer and tech certifications letters are on file in EC4 and B34.
2.1.2 CTSD-ADV-1003 calls out a comm. check.

Remarks:

The loss of communications hazard is covered in CTSD-ADV-949A, Hazard Analysis for the Z-1 Space Suit Assembly (SS) Used in One-g Operations, Hazard # 16.

HAW Approval (Use for manned, oxygen, or hazardous testing.)	**Disposition**	
Responsible Engineer, Manager or Test Director/Date:		Open/No Action
		Closed/Accepted
Branch Chief/Date: (For Closed/Accepted Disposition Only)	X	Closed/Controlled
		Closed/Eliminated